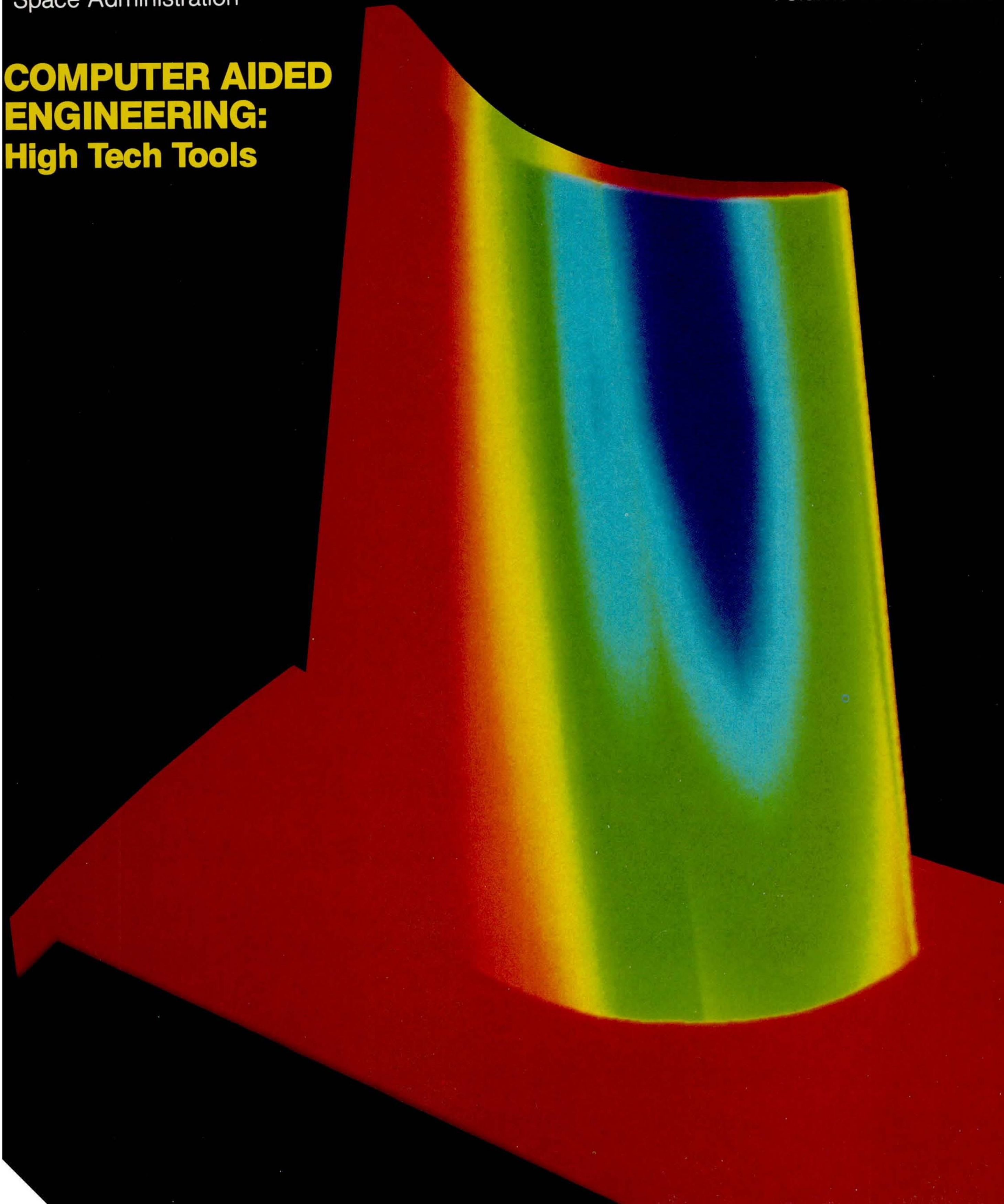
NASA Tech Briefs

National Aeronautics and
Space Administration

September 1987
Volume 11 Number 8

COMPUTER AIDED ENGINEERING:
High Tech Tools



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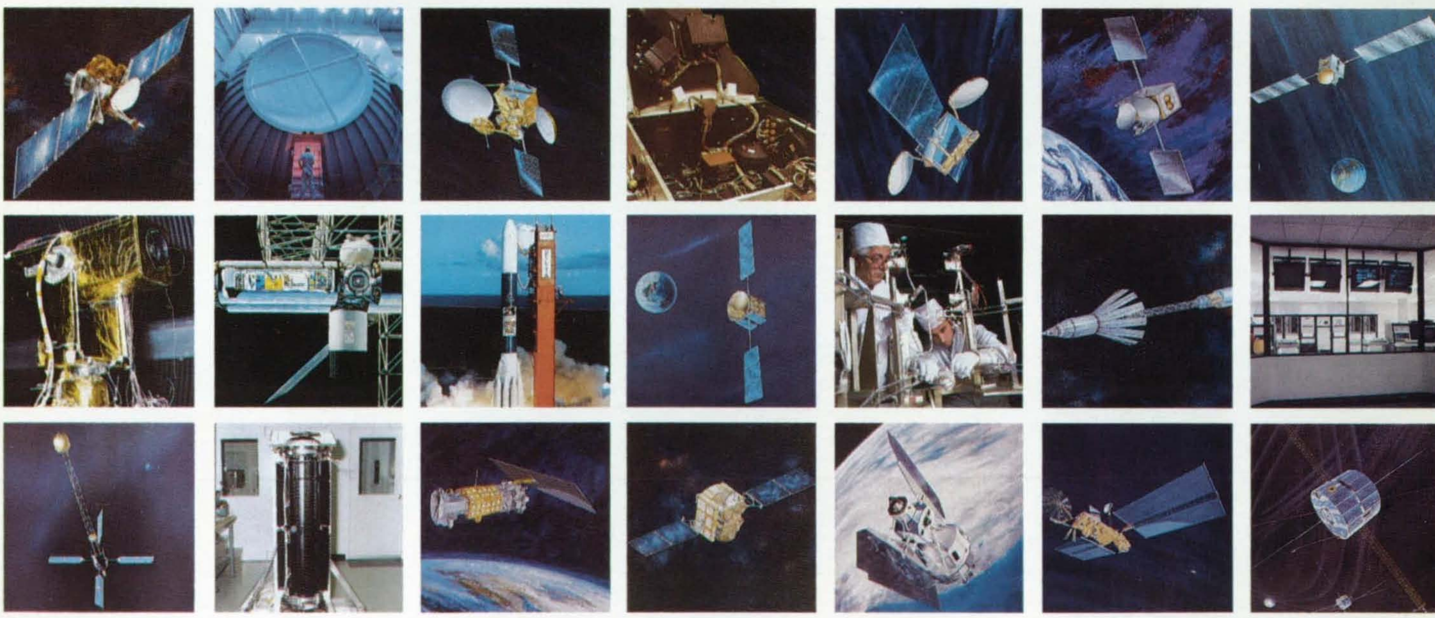

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- NASA's Advanced Communications Technology Satellite.
- Modular Attitude Control Subsystem.
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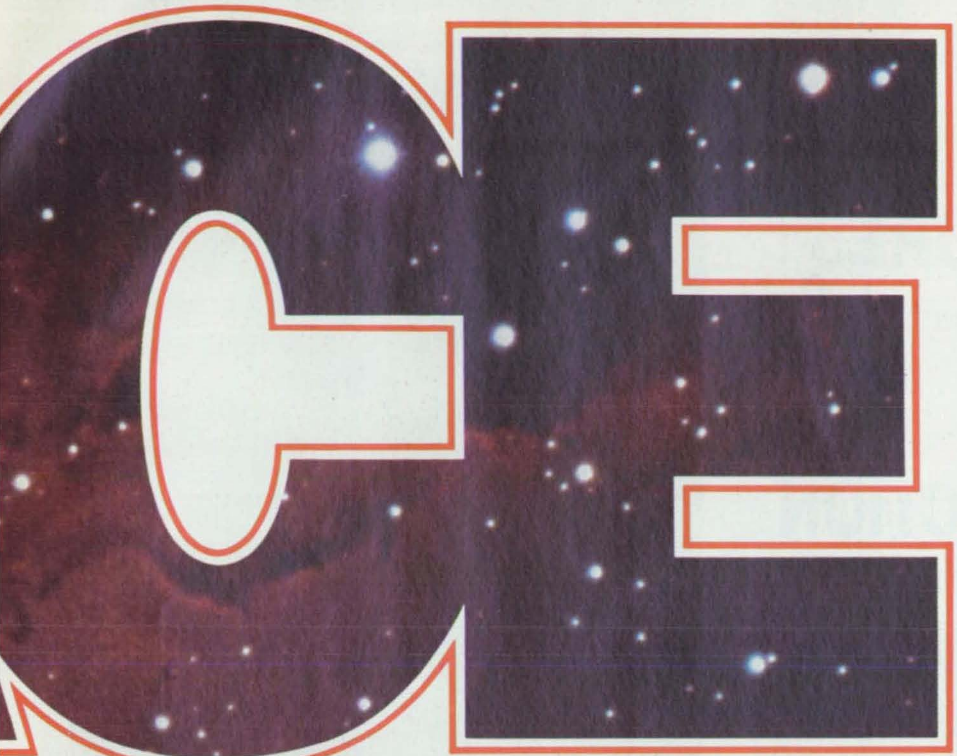
- Ultraclean Laboratory.
- SP-100, high power for space missions.
- Astro Satellite Operations Control Center.
- Transit Navy Navigation Satellite System.
- Radioisotope Thermoelectric Generator.
- DMSP, a defense meteorological satellite program.
- DSCS III, secure military communications.
- Nimbus, a meteorological sensor test bed.
- Polar Platform for the Space Station.
- Dynamics Explorer, investigation of the earth's atmosphere.

CELLENCE IN



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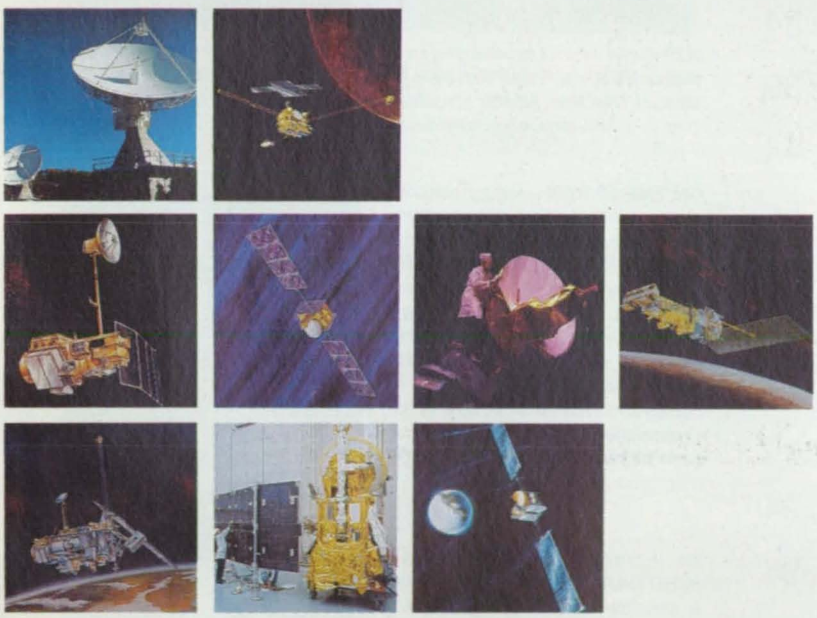

- Carpentersville Tracking, Telemetry and Control Station.
- Mars Observer, to investigate Mars.
- Landsat, monitoring the earth's resources.
- Astra 1, Luxembourg's communications satellite.
- Antenna Test Facility.
- Advanced TIROS/NOAA, a meteorological satellite program.
- UARS, upper atmosphere research.
- Integration and Test Bay.
- Spacenet, dual-band communications.

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NASA Tech Briefs
National Aeronautics and Space Administration

SEPTEMBER 1987
Volume 11 Number 8

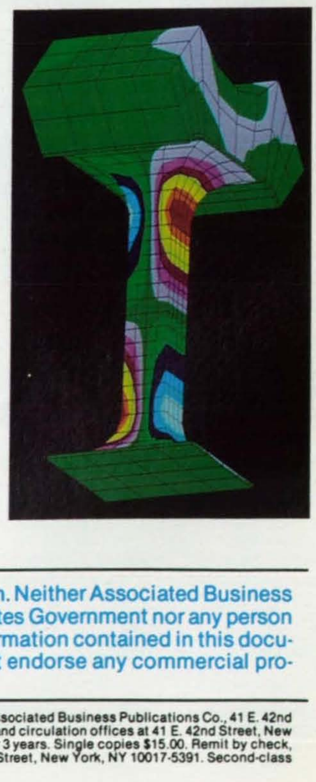
ABP BPA

SPECIAL FEATURES

TECHNICAL SECTION

A finite element model of a twelve foot high-pressure wind tunnel at NASA's Ames Research Center. This NASTRAN analysis shows the Von Mises stresses on the pressure vessel. *(Photo courtesy Mladen Chargin/Ames Research Center)*

ON THE COVER—Using continuous solid shading, this computer-generated image displays the Gaussian curvature of the geometry of a turbine blade. Color-coded Gaussian curvature values are on the right, enabling precise descriptions of the blade's geometry. Other computer-based aids to effective engineering are described in our feature story, beginning on page 8. *(Photo courtesy PDA/PATRAN)*



At Ames Research Center, NASTRAN was used to perform a flexure stress analysis of a wind tunnel model support cell. The model's "stinger" mounts on the load cell. *(Photo Mladen Chargin/Ames Research Center)*

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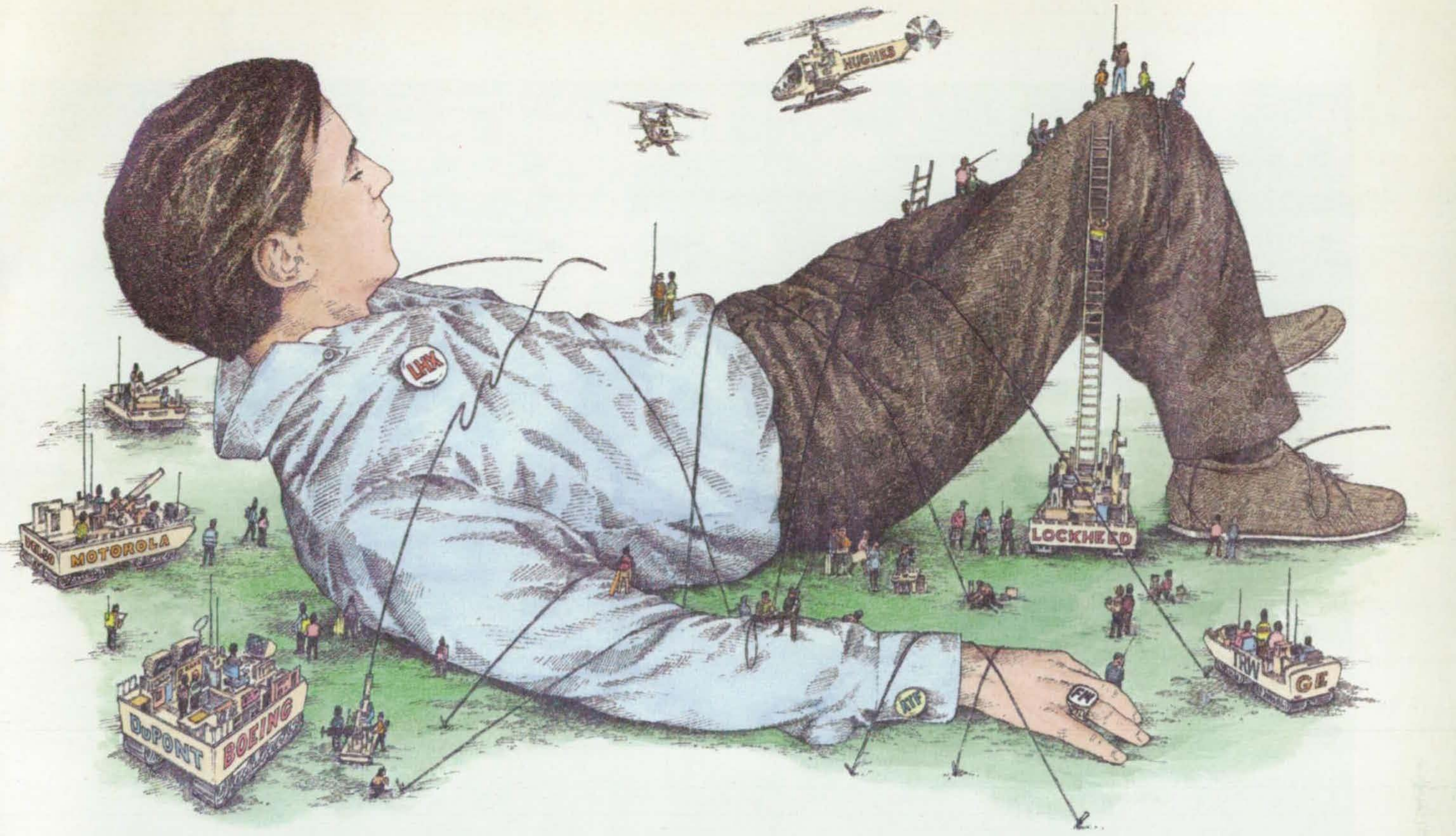

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NASA

Computer

When we were young, a friend wanted to prove that an egg, when squeezed lengthwise, would never break. He cupped the egg in his hands and pressed. Nothing happened. He strained further. His mother washed his shirt soon afterward.

Engineers used to test mechanical models like this, empirically discovering their limits, pushing them until they broke. It was an expensive, time-consuming way to verify design, but the final products worked under just about any condition. Design analysis was almost unheard of, restricted to rough estimates "within engineering accuracy." Seat-of-the-pants engineering was the way to go.

The advent of the computer changed all that, bringing with it the ability to analyze and improve a mathematical model of a design before committing it to hardware. Though empirical tests still reign as the final arbiter of safety, analysis programs have ensured that only the most worthy designs reach production. Says Myles Hurwitz, Head of the Numerical Structural Mechanics Branch at the David Taylor Naval Ship R&D Center: "No responsible engineer or analyst would say that analysis programs should replace experiments. What they do is help focus what the experiment should be. They remove designs that have no hope of working, and fine tune the experiments that should be run."

Finite element analysis programs operate on models derived from computer-aided design programs. Preprocessors apply a varying mesh to the model, breaking it down into a finite number of bite-sized pieces. The analysis programs then subject the finite element model to whatever variables are applicable, finding its limits, probing its responses and discovering any weak points. With appropriate software, the mathematical simulation responds just as a physical model would, yet the testing occurs at computer speeds. Color-coded stress patterns

Computer aided design data is an integral part of any finite element analysis. Here, an exploded 3D model of a belt tightener is displayed in perspective view using light source color shading. *(Photo courtesy VersaCAD)*

Aided Engineering

Finite element analysis programs ensure that only the most reliable designs are built. But they require careful programming to ensure the designs are accurately represented.

highlight any flaws in the design, which can then be modified at the terminal.

One of the more useful aspects of finite element analysis is its ability to do design synthesis. A way to optimize structures, design synthesis "lets the computer do most of the work; you state the problem, state your constraints, turn on the machine and let it do its thing," explains Mladen Chargin, an Aerospace Technologist in the Test Engineering and Analysis Branch at NASA's Ames Research Center. He adds, "You start out with a certain initial concept and let the computer iterate on that based on various analyses it does along the way. It will come up with a better design, one with lighter weight and higher performance."

NASA's main contribution to computerized analysis is NASTRAN®, the first general purpose finite element analysis program. Says Hurwitz: "NASTRAN put many types of structural analysis into one package, a uniform format that enabled different segments of the engineering community to use the same kind of information and perform their individualized analyses." According to Tom Butler, an engineer commonly referred to as the 'father of NASTRAN,' "We lifted NASTRAN from proprietory to public. It was easy to disseminate, easy to pick up, and it grew like wildfire."

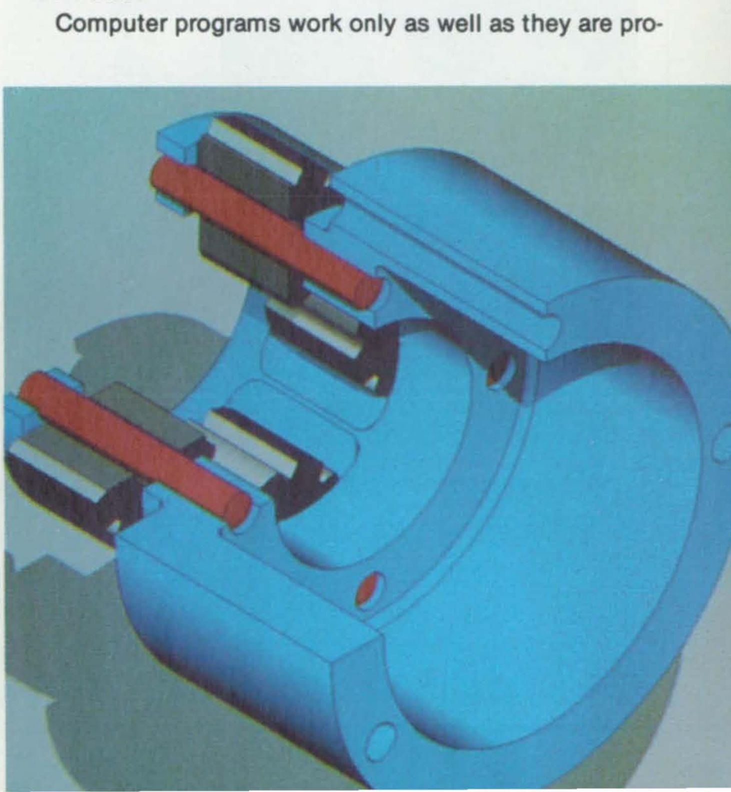
One version of NASTRAN will help bring back messages from the edge of the solar system. In August 1989, Voyager 2 will pass planet Neptune, 4.5 billion kilometers away. Radio signals from Voyager, starting their trip with about the same power as a refrigerator lightbulb, will be less powerful than a firefly glow four hours later when they reach earth. As part of an upgrade project to ensure these minuscule signals will be received, the dish antennas in NASA's Deep Space Network (DSN) will be expanded from 64 to 70 meters in diameter. Explains Dr. Chian T. Chian, a member of the technical staff in the Ground Antenna and Facility Engineering Section at NASA's Jet Propulsion Laboratory: "We are concerned with the increased vertical loading from the weight of the antenna on the pedestal. We use NASTRAN to analyze how the pedestal will behave under the wind loading, and also under the seismic loads that result from our proximity to the California earthquake zone." He adds, "Because of the structure's complexity, NASTRAN is very important and very helpful."

At Ames Research Center, a program called Sophia will place a telescope inside a Boeing 747. Mladen Chargin uses NASTRAN in several aspects of the project: "We've analyzed the Sophia telescope structure with NASTRAN, and have optimized some of its structural components to meet weight and natural frequency requirements."

A servo system will move the telescope to compensate for the aircraft's motion as the telescope tracks a star. A theoretically ideal telescope would be completely rigid, not wobbling after it was moved. That ideal hasn't yet been achieved, however, as anyone who has ever lifted a long thin plastic pipe can attest. For the Sophia telescope servo system, such variations are mathematically dealt with. As Chargin describes: "NASTRAN provides the dynamic characteristics of the telescope to the servo system and says, 'Instead of moving a rigid bar of steel, you're going to be moving this flexible thing with these characteristics.' The control engineer then designs his servo system so that the final response allows for the telescope's behavior."

Caveats

Computer programs work only as well as they are pro-



The Cadam, Inc. Solid Modeler program developed this physical representation of a planetary gear assembly. As a true volumetric description, data inherent to the assembly can be extracted for finite element analyses or for operating numerically controlled machines. *(Photo courtesy Cadam, Inc.)*

grammed, and finite element analyses are no different. To get a reliable representation of a design, the analyst must be a careful worker. Says Tom Butler of Butler Analyses: "If the analyst doesn't represent the model right, if he makes mistakes in the interpretation of the drawing, or if the loads he puts on it do not represent the design conditions, then his analysis doesn't tell him much."

A degree of coarseness intrudes as soon as a real object, having an infinity of points, is represented by a finite number of points, or elements. Though preprocessor programs automatically define the mesh elements, Butler cautions against total reliance on them. The only way to mitigate the inherent errors in a representation of a real object, Butler says, is "to zero in on problem areas to ensure that the appropriate elements are being used." He adds, "Finite elements have built-in errors. The art of modelling is to limit the effect of those errors."

If the analyst accurately portrays his design, the model can be relied on with a qualified confidence. Says Dr. Chian at JPL: "With careful modelling and reasonable detail, we get less than five percent discrepancy between our finite element predictions and the actual response. This gives us the confidence to simulate how the antenna will perform in the field, giving us a model to experiment with, right at our desk."

What does the future hold for finite element analysis? According to Michael Cooper, Manager of the Structural Analysis Section at Dynamic Engineering Inc. in Newport News, VA, "The state of the art in design analysis is still very much in the linear regime. But many of the world's problems occur in the nonlinear realm." Nonlinear problems are currently handled by isolating them from the linear part of the model, solving each problem separately, and combining the results. Such partitioning causes inaccuracies, since linear and nonlinear forces dynamically interact in the real world. Future analysis programs, able to take advantage of more powerful and affordable computers, will efficiently combine and solve linear and nonlinear problems. States Butler: "Pretty soon it'll be routine to do nonlinears, but until then, a lot of mistakes are being made."

New generations of hardware will also have their effect on finite element analysis. NASTRAN and equivalent programs currently require engineering workstations, while less sophisticated programs run on PC-ATs or equivalents. As the distinction between top-end PCs and low-end workstations continues to blur, the power of analysis comes to any engineer's fingertips. Networked engineers will also benefit. Says Myles Hurwitz: "We're talking about faster computers and faster communications, enabling an engineer to sit down at a terminal and design and analyze the part that he needs. He'll virtually instantaneously get back the results of his analysis, with color shaded graphics."

High quality graphics are indicative of the increased power engineers have with finite element analysis programs. According to Butler: "Graphics tools show how we've represented our structure, allowing us to rotate and view it to get rid of our errors. We're getting better and more reliable results because it's easier to find mistakes." He sums up, "We're doing problems that people wouldn't have believed possible 20 years ago." □

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The Conference

The conference will offer attendees a realistic assessment of today's industry and an insight into the factors that influence the direction of future programs. Sessions will examine the risks, the profit potential, the technology and the steps necessary to encourage and sustain a viable business environment. Sessions include:

Tuesday, November 17

- AA-1 How Government and Industry Worldwide will Re-Establish Access to Space
- AA-2 Transition from Public to Private Sector
- AA-3 Current and Future Launch Services: Technology Overview
- AA-4 Commercial Policy Positions Re: ELV Industry
- AA-5 Advanced Launch Systems
- EU-28 Commercial Space Project Management

Wednesday, November 18

- AA-6 Space Stations and Industrial Platforms
- EU-34 Entrepreneurs in Space
- EU-30 Venture Capital Fair
- EU-27 Commercial Space Roundtable
- RS-8 Remote Sensing Technology
- RS-9 International Barriers to Remote Sensing
- IS-22 Computer and Communication Systems
- IS-23 Information Systems: Data Collection and Analysis
- IS-24 Information Systems: Modeling and Simulation

Thursday, November 19

- AA-0 Keynote Session
- LN-26 Return to the Moon
- LN-27 Venture to Mars
- EU-33 Multi-Vendor Presentation: Research in Space
- AA-7 Re-Establishing Access to Space: Legal and Insurance Issues
- RS-11 Commercialization of Remote Sensing Data
- SC-18 Satellite Communications: Technology, Applications
- SC-20 Satellite Communications: Cost Reduction, Insurance, etc.
- SC-21 Satellite Communications: Legal Issues
- RB-1 Robotics
- AI-25 Artificial Intelligence

Friday, November 20

- EU-31 End User Issues: Financing, Legal, Insurance
- MP-12 Materials Processing: Current Applications
- MP-13 Materials Processing: Future Capabilities/Technologies
- TT-15 Technology Transfer: Spinoffs
- TT-16 Technology Transfer: Outreach Programs from Public to Private Sector

Partial Speaker List

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Mr. Shigemichi Sonoyama, *Vice President, National Space Development Agency of Japan (NASDA)*
Mr. Richard Brackeen, *President, Martin Marietta Commercial Titan Systems*
Dr. Aaron Cohen, *Director, NASA-Johnson Space Center*
Dr. John W. Townsend, Jr., *Director, NASA-Goddard Space Flight Center*
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Mr. Andrew Stofan, *Associate Administrator for Space Station, NASA*
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Mr. Bruce L. Crockett, *President, COMSAT World Systems Division*
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Dr. Peter Kleber, *Project Manager, Industrialization of Space, DFVLR*
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Mr. David O. Wicks, Jr., *President, Criterion Investments*
Mr. Ian Parker, *Editor-in-Chief, SPACE Magazine*
Mr. Gary Miglicco, *Partner, Peat, Marwick & Mitchell*
Dr. Alex Ignatiev, *Associate Director for Development, Space Vacuum Epitaxy Center, University of Houston*
Dr. Delbert Tesar, *Head, Mechanical Engineering Department, University of Texas at Austin*
Dr. David Norton, *Director, Space and Technology Research Center, HARC*
Mr. Jean-Luc Bessis, *President, Service Argos Inc.*

The Exhibits

(Exhibits open November 18)

Some of the organizations exhibiting include:

NASA, National Space Development Agency of Japan (NASDA), Aeritalia, Lockheed Missles & Space Company, Martin Marietta Manned Space Systems, Martin Marietta Denver Aerospace, General Dynamics, Ford Aerospace & Communications, McDonnell Douglas, Hercules Aerospace Company, Rockwell International Space Transportation Systems Division, Rockwell International Space Station Systems Division, Belgian Science Policy Office, IBM, Digital Equipment Corporation, Xerox Corporation, Morton Thiokol, Inc., SPOT Image Corporation, Thomson Electron Tubes and Devices Corp., Strategic Software Planning Corp., SPACEHAB, Teledyne Rodney Metals, Pilkington Electro Optics Inc., Vellox Corp., Eaton Corporation — Consolidated Controls, International Signal & Control Group, Tracor, Inc., Space Industries Partnership, Welcom Software Technology Corporation, Houston International Teleport, SPACE Magazine, PROSPACE, Fike Metal Products Division, W.L. Gore & Associates, Space Vacuum Epitaxy Center, Cincinnati Electronics Corp., Institute for Technology Development, ASCN, Aerospace America, John M. Cockerham & Associates, Inc., Space Policy, Satellite Communications Magazine, Diversified Information Services, Inc., Digital Image Inc., NASA-JSC Life Sciences Project Division, Rocketdyne and others.

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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 14). NASA's patent-licensing program to encourage commercial development is described on page 14.

Portable Speech Synthesizer

People with speech impairments can communicate better thanks to a portable speech synthesizer. A user simply enters a statement on a keyboard, and the synthesizer converts the statement into spoken words. Battery-powered and contained in a briefcase, the synthesizer can be easily carried on trips and stored conveniently under an airplane seat. The unit can be used on telephones and in direct communication. The synthesizer consists of a microcomputer with a memory-expansion module, a speech-synthesizer circuit, batteries, a recharger, a dc-to-dc converter, and a telephone amplifier, all of which are commercially available. (See page 34).

Simple, Inexpensive Servoamplifier

Certain IC's designed to serve as power amplifiers for consumer stereophonic audio equipment have been found to contain virtually all the ingredients required for single-power-supply servoamplifiers. Since these devices are high-production consumer goods, they are inexpensive and easily obtained. Such an amplifier can be used in an analog configuration to supply a proportional torque to the motor, although simpler circuits and a more efficient use of energy result when it is utilized in a pulse-width-modulation mode. (See page 30).

Portable Chamfering Tool

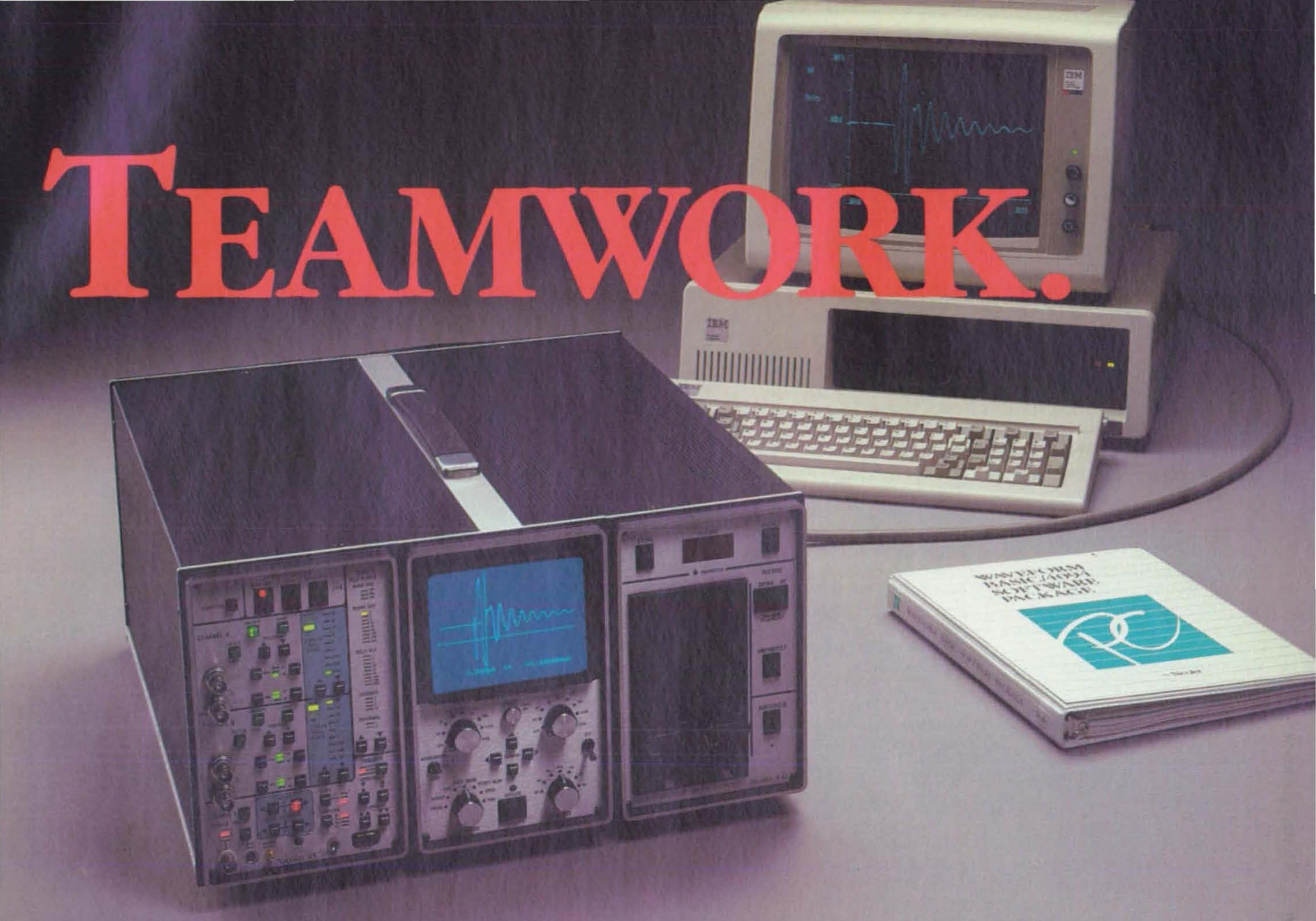
A portable machine tool precisely cuts a chamfer on a valve seat. This delicate machining operation can be done without removing the part to a machine shop. The tool can be taken to the part and used wherever pressurized air and electric power are available. It can be adapted for operations in aircraft, ships, land vehicles, and industrial machinery at sites remote from machine shops. (See page 88).

Electronic Caliper Has 1-mil Accuracy

A new electronic caliper is accurate within ±0.001 in. (0.025 mm) and provides both a printout and a digital display of thickness. Measurements take less than one-tenth the time of mechanical-micrometer measurements. A digital display and calibration unit processes the signal and displays the measured value in inches. (See page 64).

High-Lift, Low-Pitching-Moment Airfoils

Two families of airfoil shapes perform better than prior airfoil sections and can thus enhance the performances of helicopters and other rotorcraft. The specific shapes of the airfoil profiles in both families simultaneously permit high maximum lift coefficients, low pitching-moment coefficients, and high drag-divergence mach numbers, within the specified flight-performance ranges. (See page 63).



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Electronic Components & Circuits

Tester for Multiple-Conductor Cables

Faults are revealed in a pattern and sequence of lights.

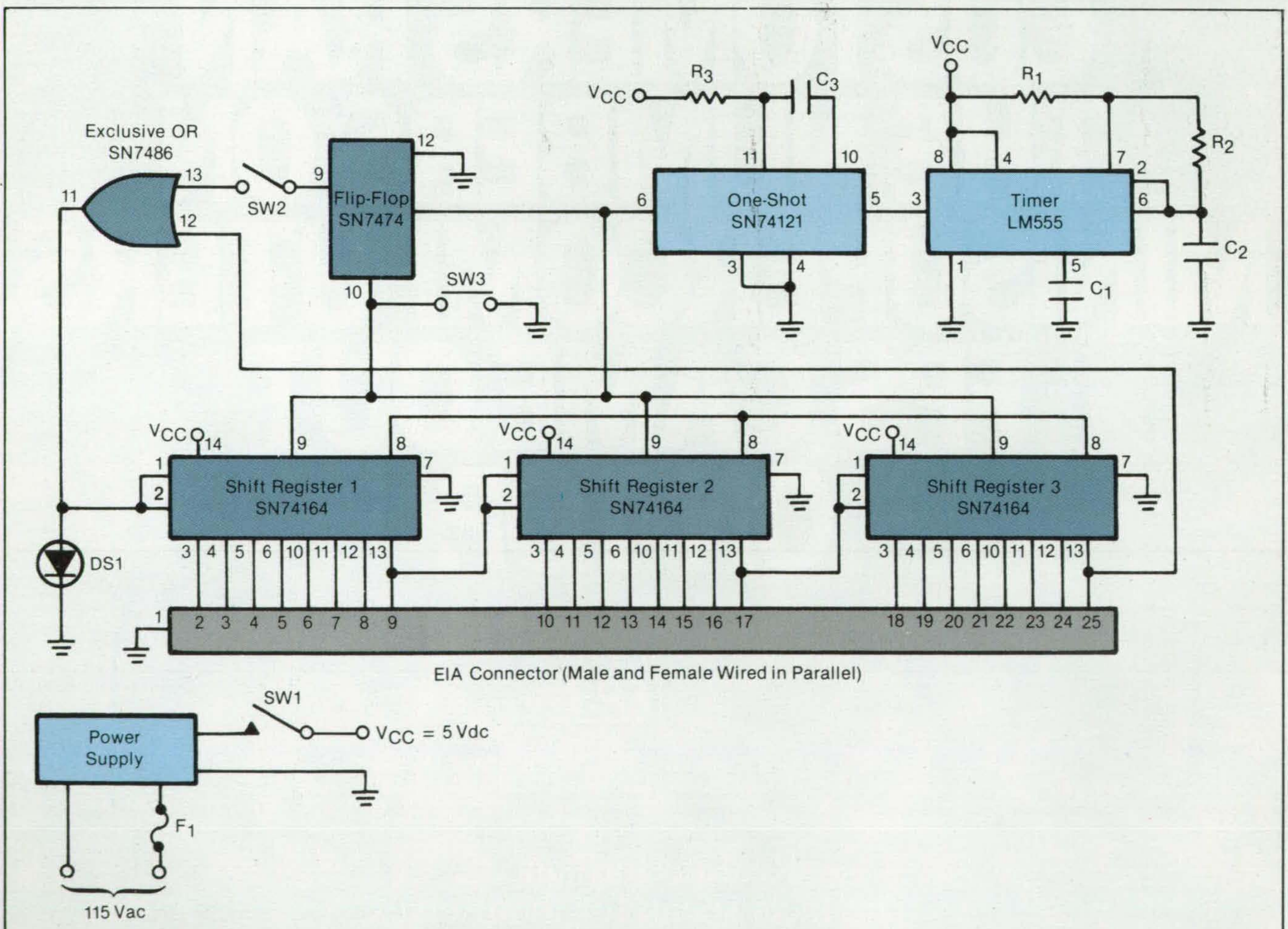
Ames Research Center, Moffett Field, California

A portable testing circuit enables a technician to determine quickly whether there are wiring errors in a multiple-conductor electrical cable or its terminal connectors. The circuit was designed for the onsite testing of standard RS232 computer-terminal cables with 25-pin connectors; the basic design can be altered for more or fewer than 25. The tester includes an active unit, which is plugged into the cable at one end, and a passive unit, which is plugged in at the other end.

The passive unit, about the size of a candy bar, contains 24 light-emitting diodes arranged in a pattern matching that of connector pins 2 through 25. The anodes of the diodes are connected to pins 2 through 25; and the cathodes, to pin 1. (Pin 1 and conductor 1 of the cable are used as the current return.)

The active unit (see figure) includes a timer, a one-shot, a flip-flop, and shift registers that apply a voltage in turn to each pin except pin 1. Switch 2 is used to select two different sequences. In sequence 1 (switch 2 closed), a voltage is applied for one-half second to pins 2 through 25 in succession. The cycle repeats after pin 25. The count can be reset to the beginning by momentarily closing switch 3. Sequence 1 is preferred by most technicians for identifying crossed connections.

In sequence 2 (switch 2 open), a continuous voltage is applied first to pin 2, then to pin 3, and so forth until the voltage is applied to all the pins. Next, the voltage is



The **Active Unit of the Tester** is made of inexpensive integrated circuits and other readily available components. The timer and one-shot generate pulses, which are counted by the shift registers. The shift-register output terminals are wired to the connector pins so that a voltage is applied to each pin in sequence.

What do you ex

"Thirty man years—that's what delivering our first automated design system would have taken using a standard workstation."

removed in turn from pins 2 through 25. The cycle then repeats. Technicians prefer sequence 2 when looking for missing connections.

To interpret the test results, it is necessary to know which pins are supposed to be connected to which conductors. For example, in a typical computer-terminal cable, pins 1 through 8, 20, and 25 of one connector should be connected through the corresponding wires to the corresponding pins of the connector at the other end. Five possible conditions might be observed in a test of this cable:

1. **Diodes 2 through 8, 20, and 25 light in sequence.** The others remain dark. This indicates a good cable with correct connections at both ends.
2. **None of the diodes lights up.** Most likely this means that pin 1 is not connected, conductor1 is interrupted somewhere, or conductor 1 is connected to the wrong pin at one or both ends. Although it is unlikely, such a test result could mean that all of pins 2 through 8, 20, and 25 are disconnected.
3. **One or more diodes light out of sequence.** For example, diode 3 lights before diode 2, then diode 4 lights, and the sequence is correct after that. This means that the connections for pins 2 and 3 are reversed.
4. **One or more diodes corresponding to desired connections do not light, or diodes light at locations for which there should be no connections.** For example, if diode 5 does not light but diode 17 does, then the wire from pin 5 at the active-unit end has been erroneously connected to pin 17 at the passive-unit end.
5. **Two or more diodes light at the same time.** For example, if diodes 2 and 3 light at the same time instead of in sequence, then there is a short between pins 2 and 3.

This work was done by Manfred N. Wirth of **Ames Research Center** *and Larry Kellogg of Bendix Field Engineering Corp. For further information, Circle 159 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11569.

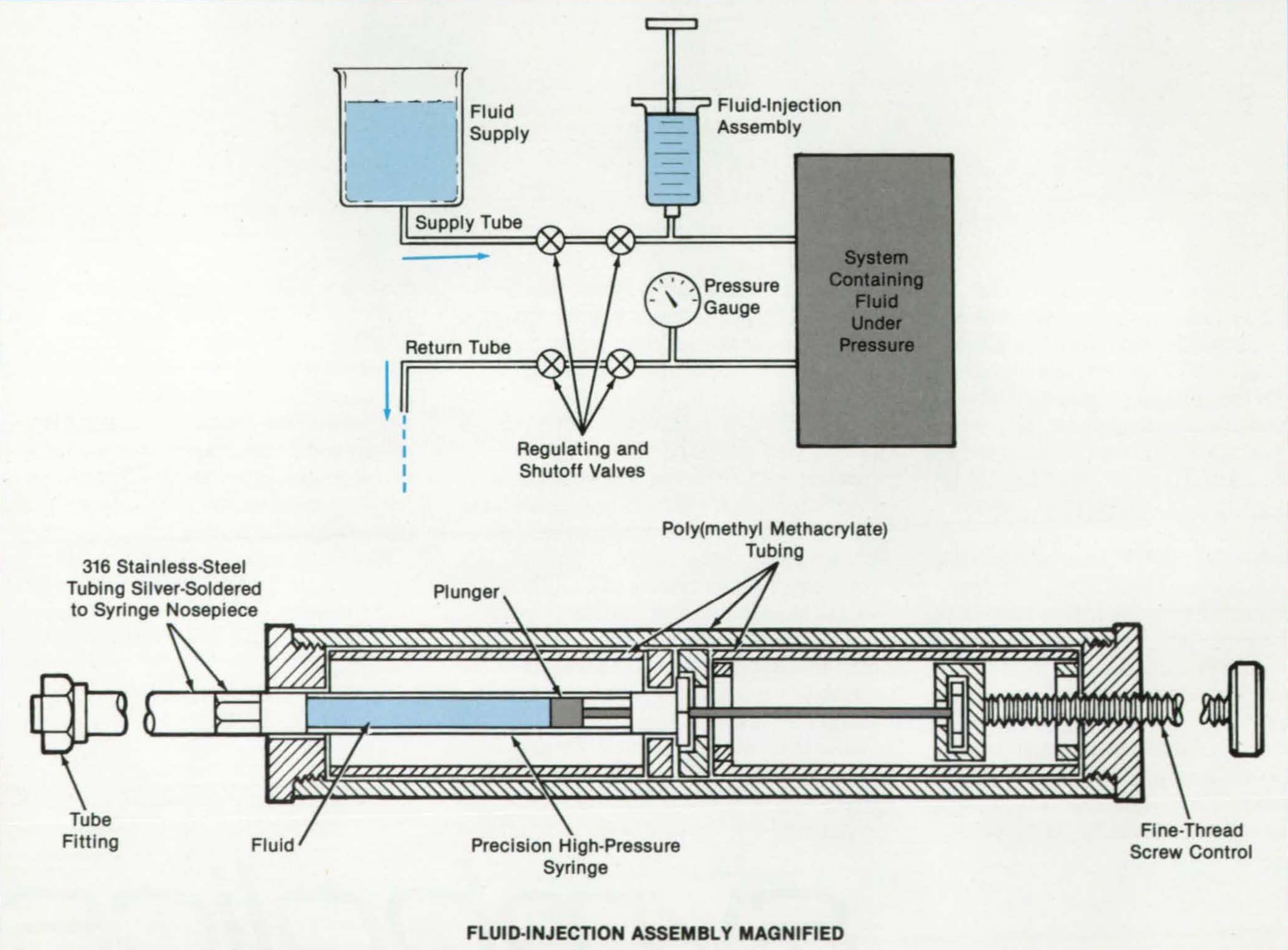
Measuring Leakage in a Pressurized-Fluid Loop

The technique can be applied to systems with inaccessible parts and connections.

Ames Research Center, Moffett Field, California

Measurement of the volume of fluid added to restore the original pressure of a closed pressurized-fluid loop or system is used to determine the leak rate. In this technique, only the supply and return ports of the system need be accessible. No "bagging" of the system is required (as is often the case with helium leak testing), and system volume need not be known.

A fluid-injection assembly and regulating and shutoff valves are connected to



Fluid Is Added to the system by the fluid-injection assembly to make up for leakage. The amount required to restore the pressure in the system is a measure of the leakage rate.

the supply port of the system, a calibrated pressure gauge and regulating and shutoff valves are connected to the return port, and a supply of pressurized fluid is connected to the supply tube (see figure). The fluid-injection assembly includes a precison high-pressure syringe enclosed in poly(methyl methacrylate) tubing. A tube fitting on one end connects to the system. On the opposite end, a fine-thread screw controls the plunger position.

The system is filled with fluid, bled, and pressurized to a nominal test pressure. The supply and return ports are sealed (regulating and shutoff valves closed) at the nominal pressure. After a suitable equilibration and stabilization period at constant temperature, the system pressure is adjusted to give an exact test-pressure indication on the calibrated pressure gauge. After a given test period (for example, 3 hours), during which the system may lose some pressure, the plunger of the fluid-injection assembly is adjusted until the initial test-pressure indication is restored on the calibrated pressure gauge. The measured volume of injected fluid divided by the elapsed test period yields the leakage rate.

The leakage rate may be determined at any required system pressure (for example, maximum system operating pressure), using any fluid that is virtually incompressible at the test pressure and that is compatible with the system materials. Very low leakage rates may be measured (for example, 0.04 cm^3/hour, or lower).

Test-joint leakage, gases in the test fluid, or inadequate system bleeding may contribute to an inaccurate measurement of the system leakage rate. However, these factors, which can be controlled, produce "worst-case" values. Such values can show that the specified system leakage rates are not being exceeded.

This work was done by Brian D. Clarke of Management and Technical Services Co. for **Ames Research Center**. *For further information, Circle 153 on the TSP Request Card.*

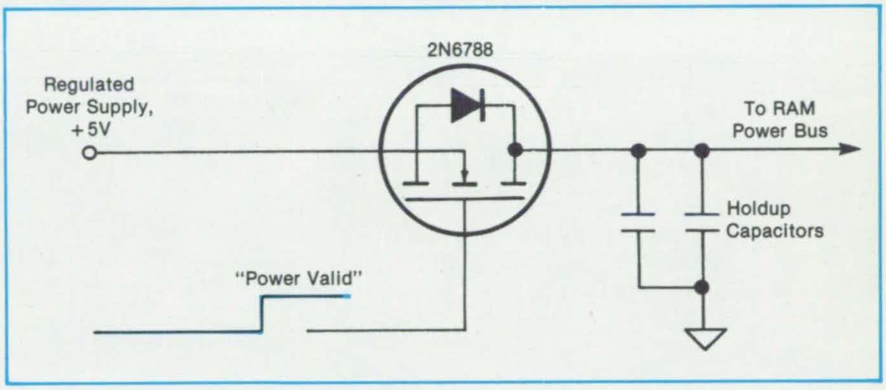
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11592

Energy-Saving RAM-Power Tap

A reverse-flow HEXFET® minimizes voltage drop and power dissipation.

Langley Research Center, Hampton, Virginia

A design for a power tap for a random-access memory (RAM) could have potential application in digital systems where conservation of power is of great importance. The RAM power is provided by placing a HEXFET® in series with a +5-Vdc main power source, as shown in the figure. The HEXFET® must be operated in the reverse direction. The normal current in an n-channel device flows from the drain to the source. In this application, current flows from the source to the drain. "Power-valid" signals are used to turn the device on and off.



The **HEXFET® Scheme** reduces the voltage drop by approximately 80 percent.

Current techniques for RAM power call for a separate power bus to be independent of the +5-V regulated power source, requiring a separate +5-V source or a tap from this source isolated with a diode. This diode causes a drop of 0.6 to 0.7 V in the RAM power. By using a HEXFET® in the reverse direction, a direct tap from the +5-V source can be made with minimum voltage drop and minimum power dissipation.

In the scheme shown, with a fully saturated HEXFET® channel resistance of 0.30 ohm and a steady-state current of 350 mA, the total voltage drop is only 0.11 V, compared with a 0.6-V drop using the isolation diode. The RAM also requires a holdup period upon loss of the main +5-V power. The "power-valid" signal generated inside the supply is used to turn the HEXFET® off, isolating the holdup capacitors from the main source to provide the necessary RAM hold-up power.

HEXFET® is a registered trademark of International Rectifier Corp.

This work was done by Alan Roy Bruner of Sperry Corp. for **Langley Research Center**. *No further documentation is available. LAR-13515*

Power-Switching Circuit

Functions of circuit breakers, meters, and switches are combined.

NASA's Jet Propulsion Laboratory, Pasadena, California

A circuit (see figure) that includes power field-effect transitors (PFET's) provides on/off switching, soft starting, current monitoring, current tripping, and protection against overcurrent for a 30-Vdc power supply at normal load currents up to 2 A. Unlike the double-pole, single-throw, relay-driven mechanical switch that it replaces, it has no moving parts. Under the "fail-safe" circuit design, the failure of any single component can result in an open switch but not in a closed one: thus, two such circuits can be wired in parallel to obtain immunity to any single-point failure.

The switch is turned on by an "on" command pulse; it is turned off by an "off" command pulse. An overcurrent trip can also be set on the bus side by a 6-digit binary signal, which is converted to an analog voltage and compared with the amplified voltage developed across a load-current-sensing resistor. As a backup, a fixed reference voltage provides a tripping current of about 3 A on the return side. When the current exceeds either tripping current, a comparator triggers a flip-flop that provides a logic signal to turn off one of the PFET's. The flip-flop can be triggered to turn the current on again with the same or a different tripping current. Thus, the circuit

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—DoD Directive 3405.2, 3/30/87.

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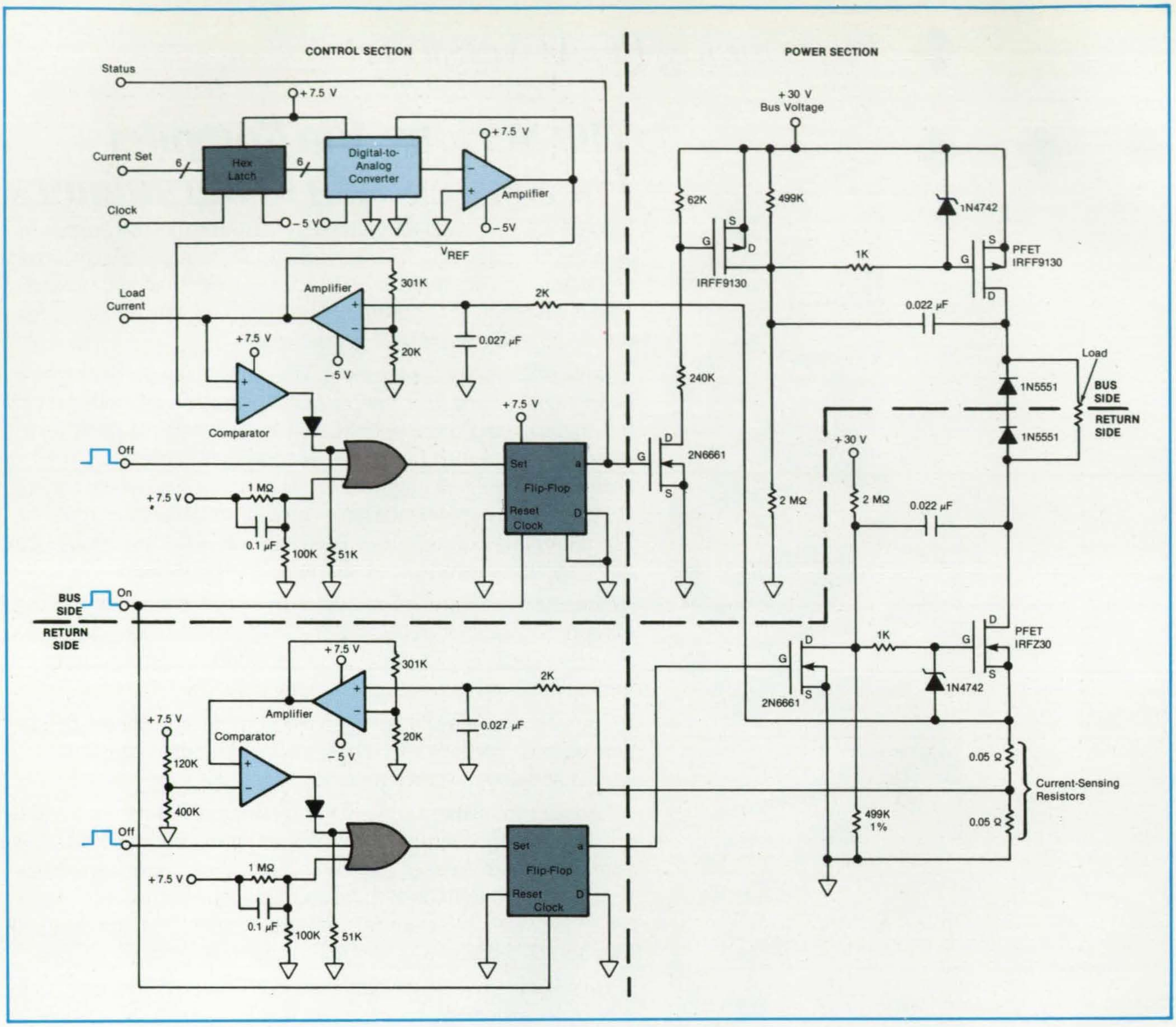
—DoD Directive 3405.1, 4/2/87.

AdaNow



The **Switching Circuit** acts as an adjustable, resettable, circuit breaker with no moving parts.

acts as an adjustable, resettable circuit breaker.

Resistor/capacitor combinations (0.027 μF, 2 kΩ) at the inputs of the current-sensing amplifiers act as low-pass filters: this introduces a few hundred μs of delay in the response to overcurrent, thereby providing some immunity to noise. The delay does not seriously degrade protection against current surges: the resistive voltage divider for the gate of the return-side PFET sets the bias at a level that allows the PFET to conduct no more than 10 A.

The 0.022-μF capacitors connected to the drain terminals of the PFET's provide a Miller effect, which reduces the rate of change of the drain voltage and therefore the rate of rise of current at turn-on. The soft-turn-on time depends upon the load impedance and is typically 100 to 200 ms.

This work was done by Gerald A. Praver, Peter C. Theisinger, and John Genofsky of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 147 on the TSP Request Card.*
NPO-16874

Modified-Edge Compact-Range Measurement System

A large edge curvature reduces unwanted diffraction.

Langley Research Center, Hampton, Virginia

The compact range is an electromagnetic-measurement system used to simulate a plane wave illuminating an antenna or scattering body. The plane wave is necessary to represent the use of the antenna or scattering from a target in a real situation. Traditionally, a compact range has been designed as an offset-fed parabolic reflector with a knife or a serrated edge. The edge termination of the parabolic surface has limited the extent of the plane-wave region or, more significantly, the antenna or scattering-body size that can be measured in the compact range. As a result, the compact range has had limited use as well as limited accuracy. The compact-range concept has not been applied to larger systems because of the large discrepancy between the target and reflector sizes.

The signal reflected by the parabolic reflector is basically a plane wave, which exists over the extent of the surface. If a simple straight edge is used, the diffracted signal is quite strong about the edge (see Figure 1). This diffracted signal interferes with the plane wave, causing amplitude

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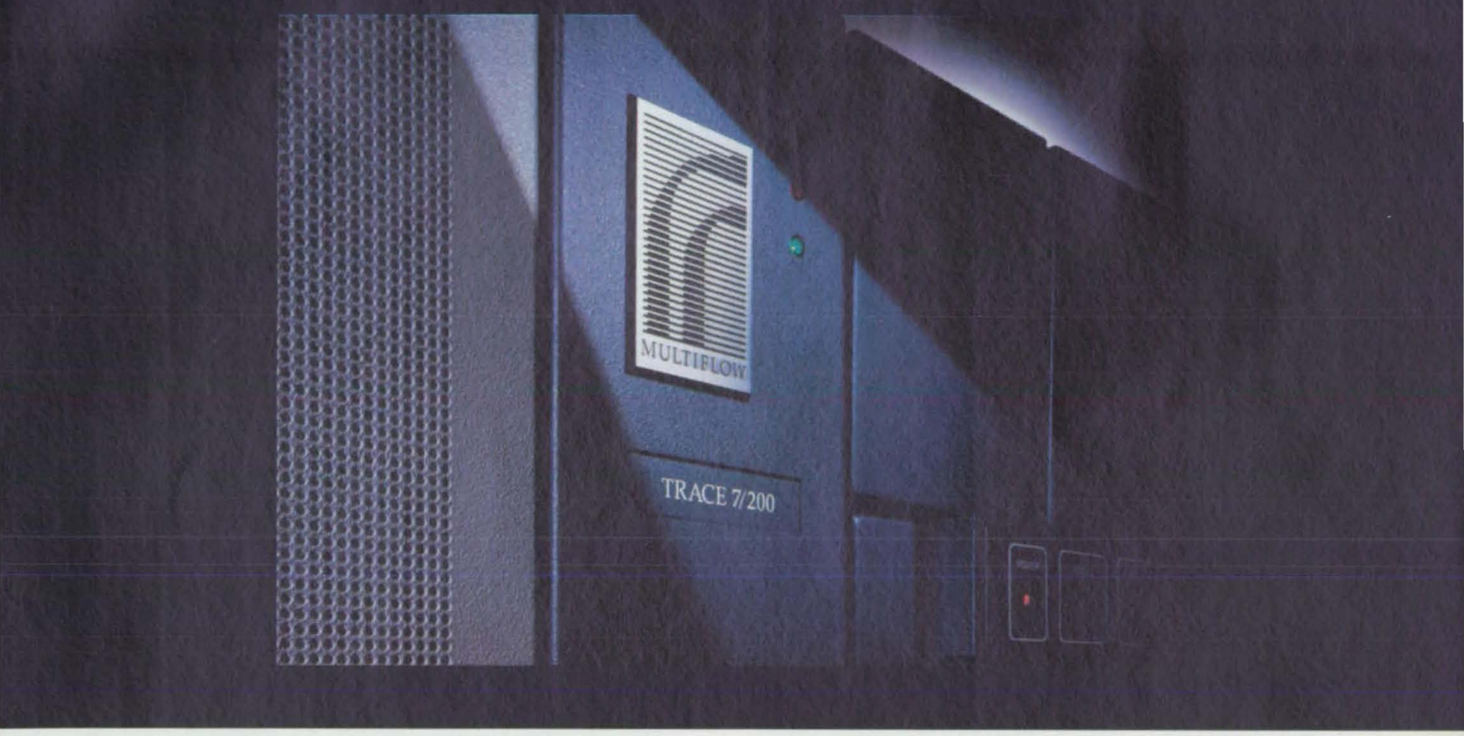

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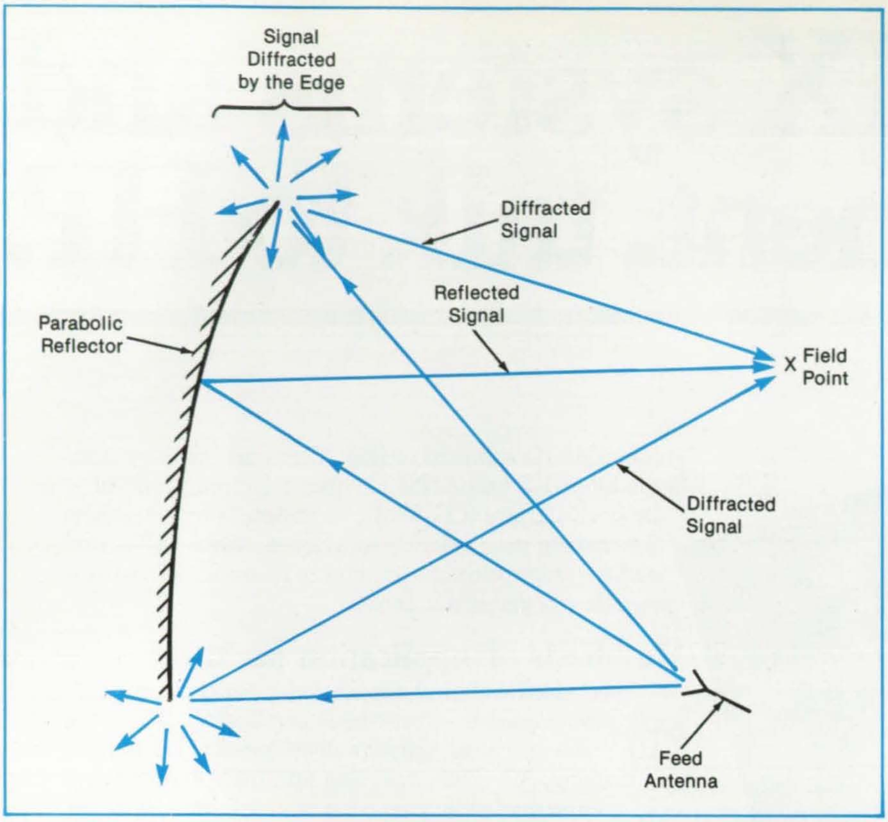

Figure 1. **Signals Diffracted by the Knife Edge** in a conventional system typically interfere with the plane wave reflected from the paraboloid.

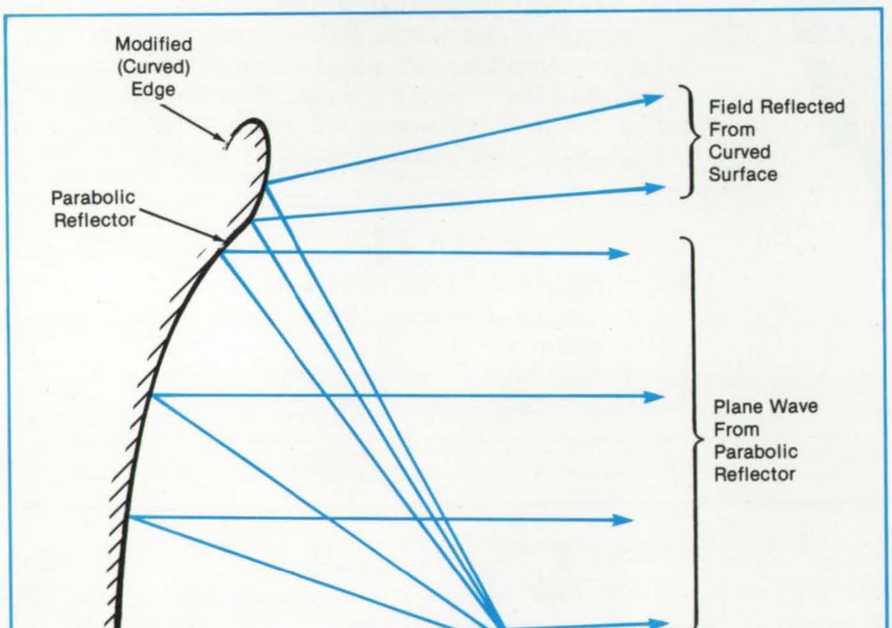

Figure 2. When the **Edge Termination of the Reflector** is a large curved surface, the field diffracted by the edge region is reduced by an order of magnitude.

and phase variations of the field illuminating the test antenna or scattering body. Several schemes to overcome this problem were examined, and it was found that a large, curved edge termination is most appropriate, as shown in Figure 2. The large, curved edge termination reduces the edge-scattered field in the target area by one order of magnitude.

The large, curved-edge treatment, which involves a radius of curvature equal to or greater than the focal distance, provides this improvement by creating a reflected field that goes smoothly from the parabolic surface to the curved surface termination. If a subreflector is used, a knife edge on the subreflector leads to excessive ripple for the main-reflector illumination. Again, this problem can be overcome by use of a large, curved edge termination. Thus, the use of large, curved edge termination on the subreflector and the main reflector provides a significant enhancement in the compact range system.

Several characteristics specify the curved-surface design. First, the radius of curvature of the curved edge at the juncture (the connecting line between the reflector and the curved edge) should be greater than the focal length of the reflector. Second, the curved surface should be smooth to a one-hundredth of a wavelength near the juncture, but the roughness can increase to a one-tenth of a wavelength at the highest frequency. The surface should continuously curve away from the focus so that the minimum radius of curvature is nowhere less than a one-quarter wavelength at the lowest operational frequency. The curved surface should also continue smoothly into the shadow region.

This approach can be used on any type of reflector, such as parabolic, elliptical, hyperbolic, or optimal. Also, the reflector can be either circularly symmetric, spherically symmetric, or cylindrical. In fact, the large, curved-surface edge-termination concept can be used on any reflector configuration requiring creation of a field without diffraction from edge terminations.

This work was done by Melvin C. Gilreath of **Langley Research Center** *and Walter D. Burnside of Ohio State University. For further information, Circle 155 on the TSP Request Card.*
LAR-13352

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Electron backstreaming is reduced.

Lewis Research Center, Cleveland, Ohio

A significant increase in the overall efficiency of traveling-wave tubes (TWT's) has been brought about by the conception and development of the multistage depressed collector (MDC). However, there are still some unresolved problems that hamper further improvement. The use of copper as an electrode material causes excessive backstreaming of reflected primary and secondary electrons. The re-emitted electrons backstream or return to the TWT interaction region, degrading not only the tube efficiency but also the quality of the output radio-frequency (RF) signal as well.

Investigation revealed that various forms of carbon exhibited substantially lower secondary electron emission characteristics than did copper, the industry standard for MDC electrode material. A form of graphite was found to meet the collector requirements and to have no major disadvantages. This graphite is a fine-grained, high-purity, isotropic material with interconnecting porosity that enables outgassing to be completed rather quickly during vacuum bakeout. Graphite with these properties is made by a variety of manufacturers; the specific material used in this study is a purified grade, DFP-2, manufactured by the POCO Graphite Co.

The coefficient of thermal expansion of this graphite matches that of alumina very closely, and these two materials can be brazed without any serious problems, using a suitable active-metal brazing alloy. Such brazing is essential to the fabrication of a rugged and reliable collector.

A novel design approach not only tied the various requirements together but also improved the manufacturability of the MDC as well. Each of the several electrode stages of the MDC was constructed in a modular form as shown in Figure 1. Each module was a brazed, axisymmetric composite, which included the graphite electrode at the center, surrounded by a ring of high-purity ceramic high-voltage insulator, and contained within an outer metal sleeve that served as the vacuum housing. The modules were then stacked, one on top of the other, to form the multiple-tiered arrangement of staged electrodes making up the collector assembly (see Figure 2).

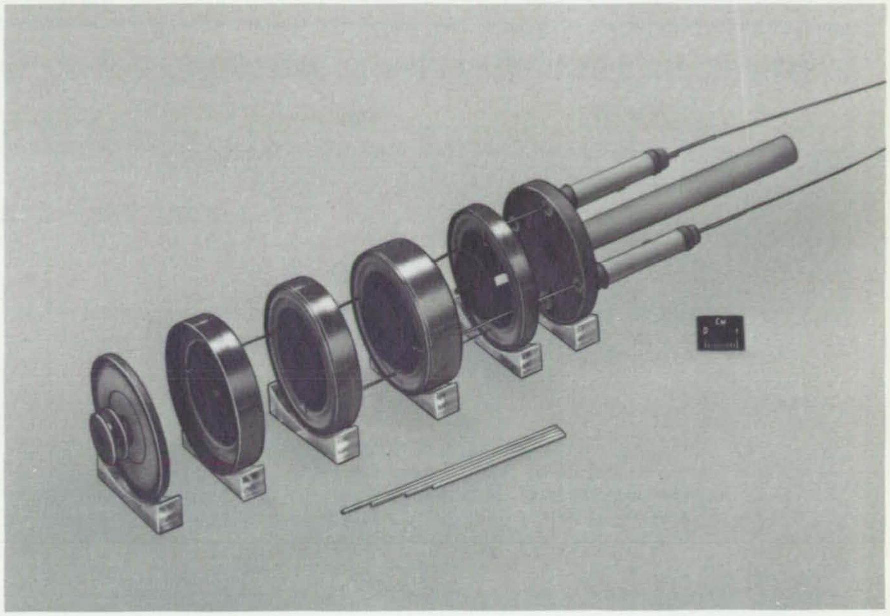


Figure 1. These **Brazed Electrode Modules** are the components of a multistage depressed collector.

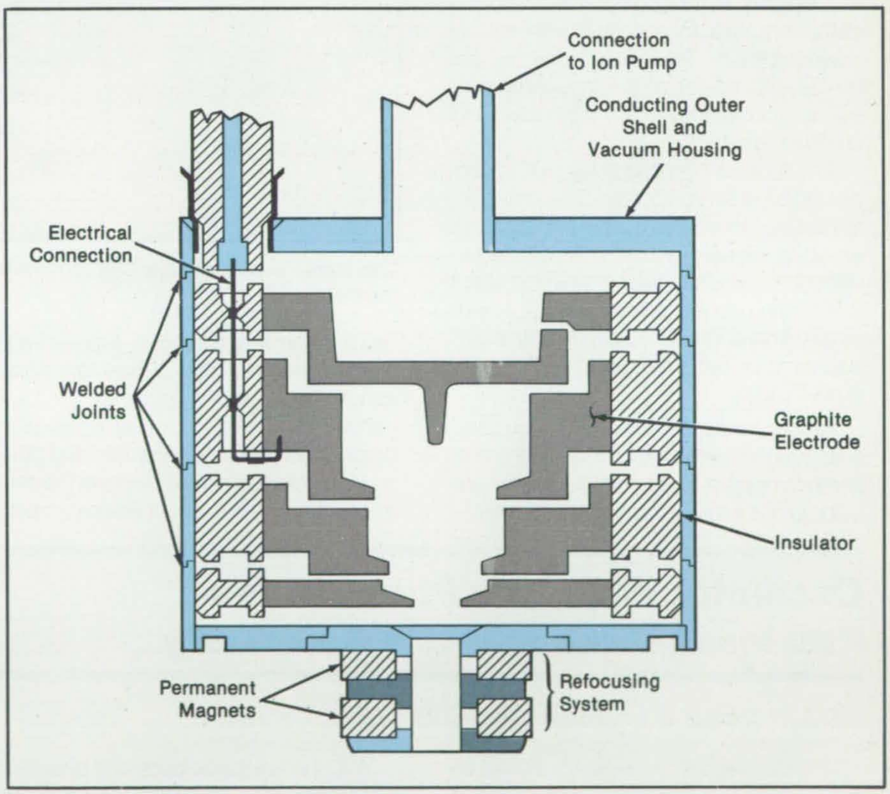


Figure 2. The **Multistage Depressed Collector** is assembled from the stack of modules shown in Figure 1.

Other good features to be found in the design include methods to hold dimensions and alignments accurately; interchangeability for replacement of any module; ease of modification of the electrode configuration and/or surface texturization; and convenience of inspection and cleaning, if necessary, of the high-voltage insulators before assembly is completed by welding the joints between modules.

The wider user of this or similar graphite material, along with the joining technology, is possible outside the communication industry. For example, there is a need for a high-temperature-resistant material like carbon that can absorb, collect, or shield high-power-density radiations like laser beams and charged particles without suffering damage.

This work was done by Ben T. Ebihara of

Lewis Research Center. *Further information may be found in NASA TP-2524 [N86-13643/NSP], "Verification of Computer-Aided Designs of Traveling-Wave Tubes Utilizing Novel Dynamic Refocusers and Graphite Electrodes for the Multistage Depressed Collector."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

This invention has been patented by NASA (U.S. Patent No. 4,527,092). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center [see page 14]. Refer to LEW-14098.

Simple, Inexpensive Servoamplifier

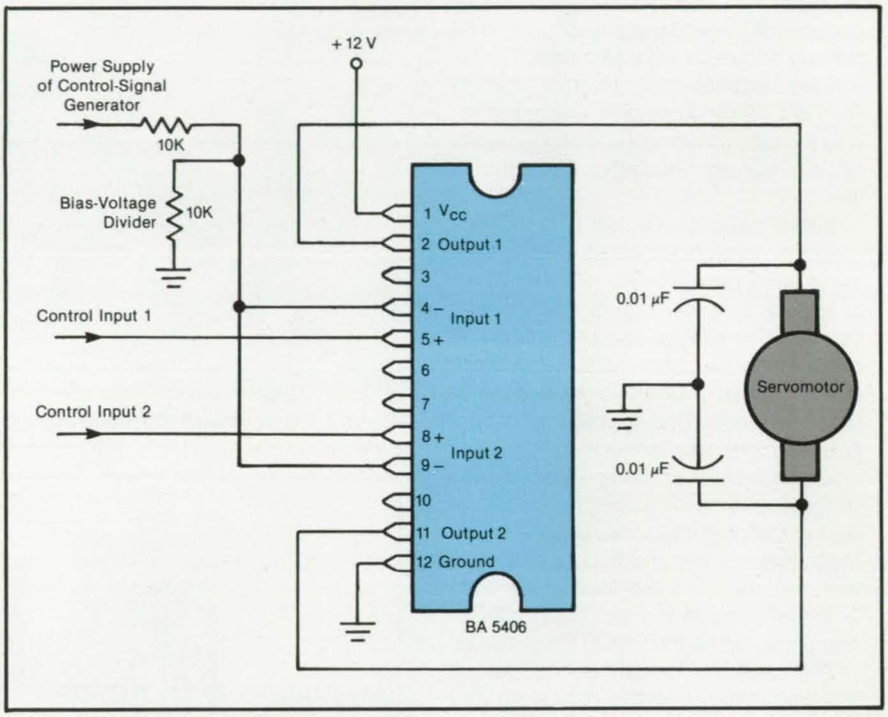
A circuit is based on a consumer-market audio-amplifier chip.

Langley Research Center, Hampton, Virginia

Low-cost, permanent-magnet dc motors can be used as relatively high performance servomotors in many instrumentation and control applications. However, when such a servo must be powered by a single power supply, as in aircraft and automotive applications, the driving amplifier becomes rather complex, and the circuitry becomes quite complicated. Special integrated circuits (IC's) capable of driving the motor in either direction are becoming available, but they are relatively expensive and difficult to obtain at present.

Certain IC's designed to serve as power amplifiers for consumer stereophonic audio equipment have been found to contain virtually all the components and circuits required for single-power-supply servoamplifiers. Since these devices are manufactured for high-production consumer goods, they are inexpensive and easily obtained.

The figure shows one of these IC's connected as a servoamplifier. The chip contains two dc power amplifiers, each of which is capable of driving its output terminal to ground potential or to within about 2 V of the positive potential of the power supply. This particular IC can supply over 1 A to a motor load when powered by a 12-V power supply.



This **Stereo Audio Amplifier Chip**, connected as a servoamplifier, can supply more than 1 A to the motor.

Although such an amplifier can be used in an analog configuration to supply a proportional torque to the motor, simpler circuits and a more efficient use of energy result when it is utilized in a pulse-width-modulation mode. The pulse-width signals can be generated directly by computer software or by an external pulse-width-modulation generator. Further, the pulse-width modulator can be designed to serve as an interface between the servoamplifier and either an analog or a digital control system.

This work was done by H. Douglas Garner of **Langley Research Center**. *For further information, Circle 26 on the TSP Request Card.*
LAR-13538

Oscillator With Low Phase Noise

Phase errors are cancelled for high frequency stability.

Goddard Space Flight Center, Greenbelt, Maryland

A radio-frequency oscillator achieves high stability of frequency through a parallel, two-amplifier configuration in which the effects that cause phase noise tend to cancel each other. The circuit includes two amplifiers with resonating elements, each of which constitutes part of the feedback loop of the other. Both generate the same frequency because each circuit provides the other with the conditions necessary for oscillation.

With the feedback loops and parallel input connections shown in the figure, the capacitive input susceptance of circuit 1 provides circuit 2 with negative conductance, while the inductive input susceptance of circuit 2 provides circuit 1 with negative conductance. The resulting total closed-loop conductance is negative — a condition that gives rise to oscillation. In effect, circuit 1 operates as a Hartley oscillator, while circuit 2 operates as a Colpitts oscillator. The common resonant frequency is given by

$$f = (2\pi)^{-1}[(C_1 + C_2)/(L_1 + L_2)C_1C_2]^{1/2}$$

The quiescent operating point is established by the supply voltage; the voltage divider R_3, R_4, R_{C1}, R_{C2}, and the common emitter resistor R_E. C_B, C_E, C_{C1}, and C_{C2} are large bypass and coupling capacitors. The tap for C_B on R_4 is used to introduce a controlled amount of negative feedback, thereby reducing the excess

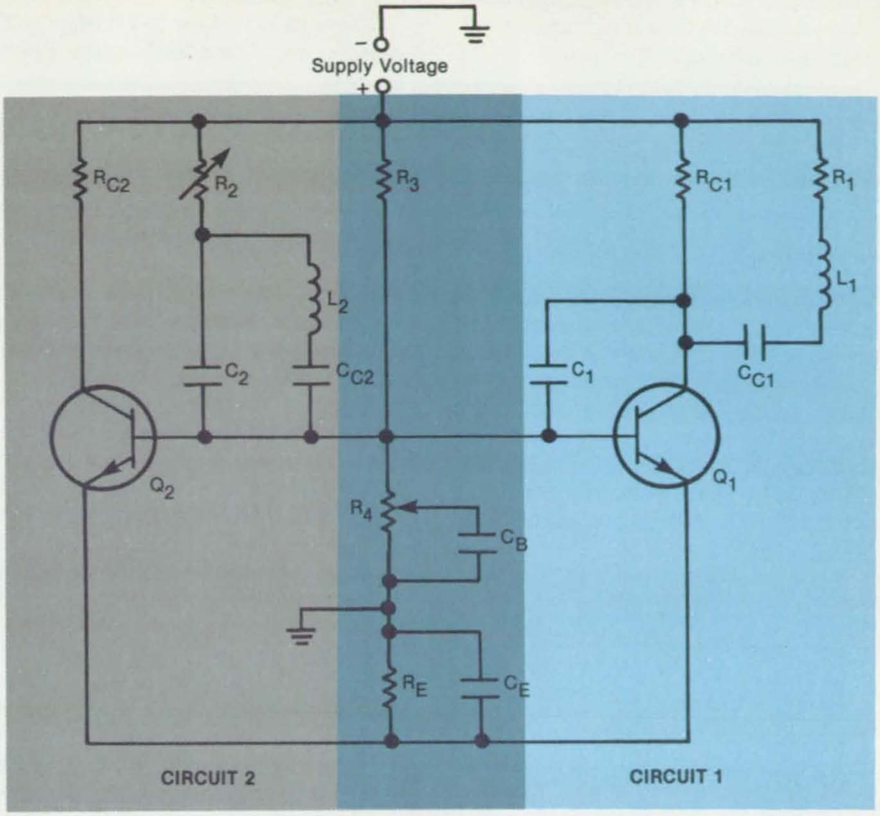
gain and limiting the severity of clipping of the sinusoidal oscillations. This promotes frequency stability because the clipping would otherwise introduce noise, which would cause the frequency to fluctuate. R_3 and R_4 are chosen to set the quiescent bias voltage at the bases equal to half the supply voltage. This helps to assure the symmetry of the oscillations, thereby further reducing clipping and contributing to frequency stability.

Q_1 and Q_2 are matched npn transistors. Resistors R_1 and R_2 are used to equalize the amplifier gains; ordinarily, one would strive for $g_{m1}R_1 = g_{m2}R_2$, where g_{mi} = the transconductance of the *i*th transistor.

In a conventional oscillator, the small fluctuations of quiescent current due to inherent noise produce instantaneous changes of phase and, therefore, of frequency. However, in this oscillator, the noise causes opposing fluctuations in capacitive and inductive input susceptances that arise from C_1 and L_2. As a result, when there is a fluctuation in the frequency of circuit 1, there is an equal (in magnitude) but opposite fluctuation in the frequency of circuit 2. Thus, the frequency stability of the combined circuits is enhanced.

This work was done by Leonard L. Kleinberg of **Goddard Space Flight Center**. *For further information, Circle 139 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 14]. Refer to GSC-13018.



In the **Low-Phase Noise Oscillator**, phase fluctuations in circuit 1 are opposed by phase fluctuations in circuit 2. The net effect is low phase noise and consequent frequency stability. In the resonant circuits, L_1 and L_2 could be replaced by piezoelectric crystals of the desired resonant frequency.

Clipper for High-Impedance Current-Drive Line

Clipping is achieved at low currents without unacceptable leakage.

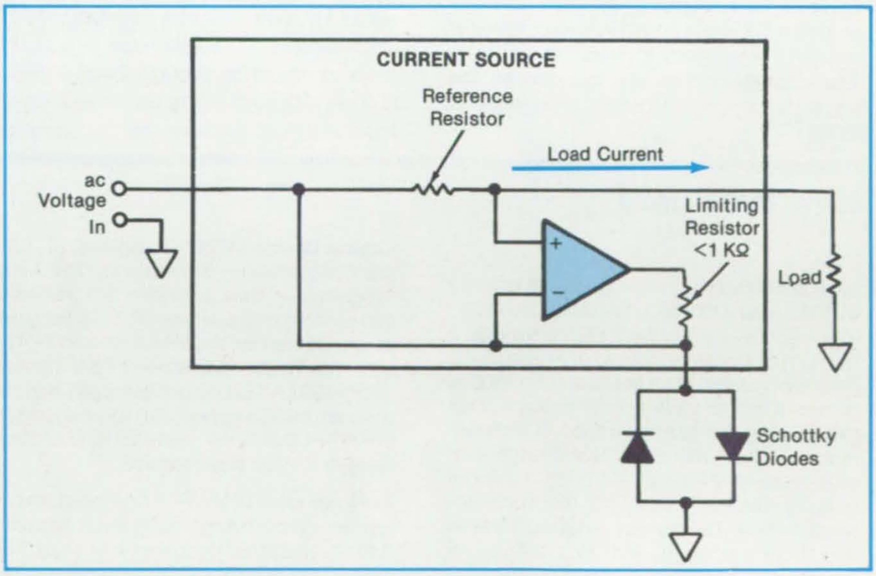
Goddard Space Flight Center, Greenbelt, Maryland

A clipping circuit limits the output voltage of a high-compliance, 1-μA current source without introducing unacceptable leakage over that necessary to make the current source work. A typical application would be in the circuit of a germanium resistance thermometer in a cryogenic system.

Leakage currents limit the usefulness of a conventional clipping circuit at small load currents (typically, microamperes). In the new circuit (see figure), leakage is reduced by shunting current through the saturated input at an operational-amplifier follower that is already part of a Howland (or equivalent) current source.

In normal (nonclipping) operation, the amplifier in the follower operates in a closed feedback loop and consequently presents the high common-mode input impedance to the current-drive line. When the voltage on the current-drive line exceeds the cut-in voltage of the two diodes, the amplifier saturates as it attempts to drive current through the diodes.

The saturation of the amplifier opens the feedback loop, thereby presenting, to the drive line, the much lower differential input



An **Operational-Amplifier Follower Circuit** is part of a variable-resistance current shunt.

resistance, which is low enough to shunt current from the drive line. Thus, smooth clipping is achieved with a minimum of additional components.

This work was done by Christopher E. Woodhouse of **Goddard Space Flight Center**. *No further documentation is available.*
GSC-13069

Electron-Focus Adjustment for Photo-Optical Imagers

The internal electron focus is made independent of the optical focus.

Goddard Space Flight Center, Greenbelt, Maryland

A procedure enables the fine tuning of the internal electron-focusing system of a photo-optical imager, without complication by the imperfections of the associated external optics. The procedure is applicable to an imager in which electrons are emitted from a photocathode in the optical focal plane, then electrostatically and/or magnetically focused to a replica of the image in a second focal plane containing photodiodes, phototransistors, charge-coupled devices, multiple-anode outputs, or other detectors (see Figure 1).

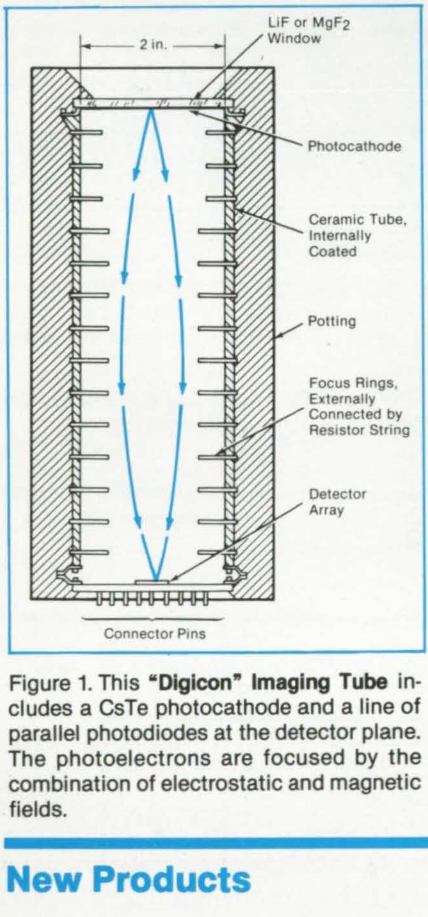


Figure 1. This **"Digicon" Imaging Tube** includes a CsTe photocathode and a line of parallel photodiodes at the detector plane. The photoelectrons are focused by the combination of electrostatic and magnetic fields.

During the adjustment procedure, the photocathode of the imager is illuminated by a monochromator containing a lamp that emits at least some light at a wavelength less than half the long-wavelength limit of the photocathode response. The operating principle is based on the fact that a photon having an energy of more than twice the band gap of the photocathode material sometimes produces two photoelectrons. The pulse from a two-photoelectron photo-detection event is twice as large as that from a single-photoelectron event. The two kinds of events can therefore be distinguished by sending the imager output to a pulse-height analyzer. For this purpose, the monochromator output must be just intense enough to enable the convenient counting of individual pulses.

The electrostatic focusing voltage or the magnetic focusing current is varied slowly. Meanwhile, the photocurrent from one of the detectors is fed to a multichannel analyzer, the output of which is recorded. The ratio of counts in the two-electron peak to the counts in the one-electron peak is then plotted as a function of the focusing voltage or current (see Figure 2).

It has been found that the ratio reaches a peak when the voltage or current is at the value for best electron focusing: this is because both photoelectrons of a double emission must be brought back together (that is, focused) to the same spot on the focal plane to achieve the double-amplitude output. Thus, the count ratio can be used to indicate the electron focus and to facilitate diagnosis when attempting to distinguish between optical and electronic causes of image degradation.

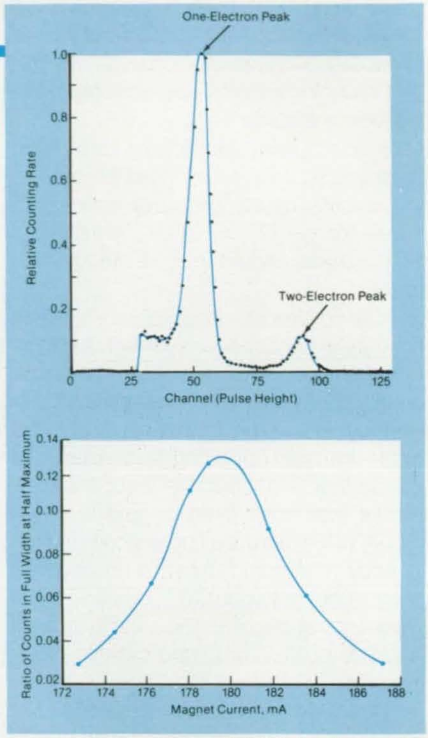


Figure 2. The **Pulse-Height Analyzer Output** is measured at various levels of magnet current. The ratio of heights of two-electron to one-electron peaks is plotted as a function of magnet current. The peak indicates best focus.

This work was done by Walter B. Fowler, Keith Flemming, and Michael M. Ziegler of **Goddard Space Flight Center**. *For further information, Circle 93 on the TSP Request Card.*
GSC-12890

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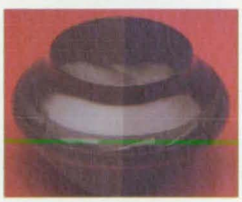

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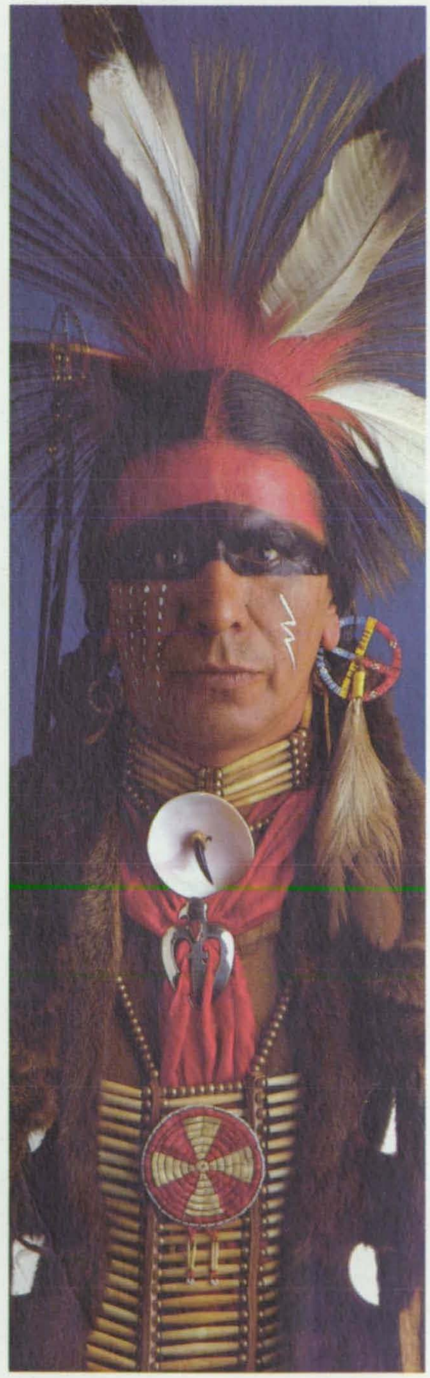

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Electronic Systems

Redundant Control for Air-Circulation Valves

Helicopter-rotor control remains even if two computers fail.

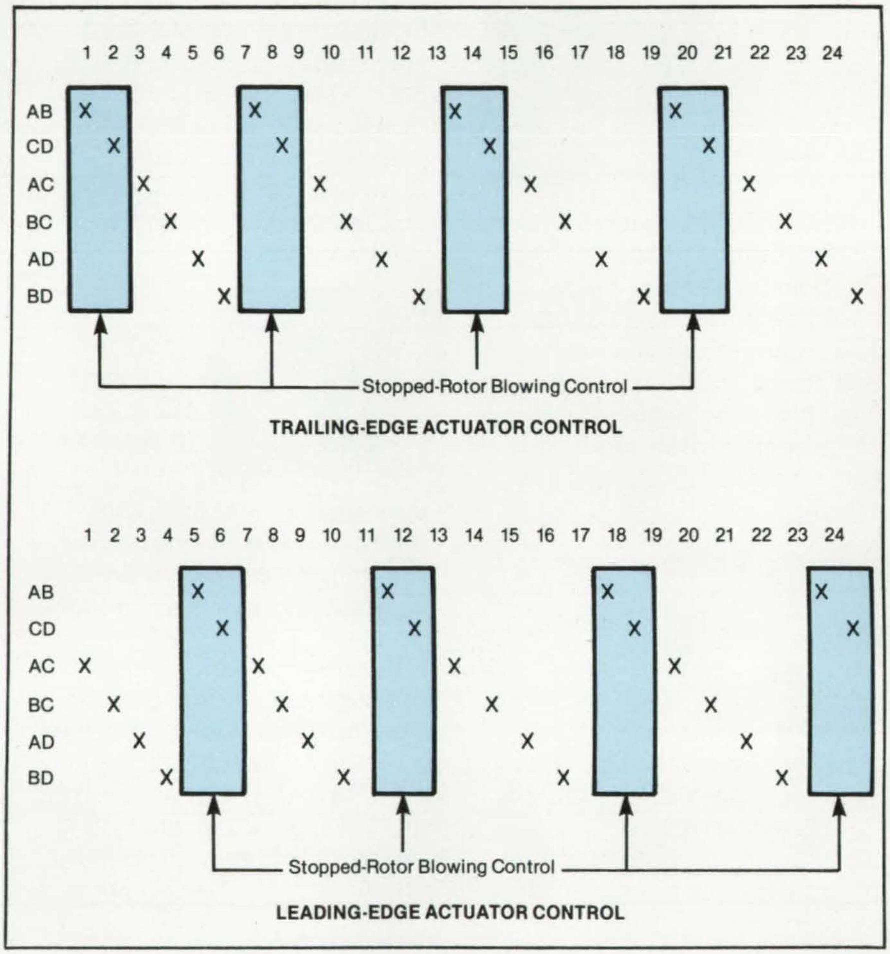
Ames Research Center, Moffett Field, California

Four computers that control airflow to an "X-wing" helicopter rotor have been arranged in a redundant configuration that ensures that the circulation control of the rotor will continue to function even if two of the computers fail. The rotor uses 48 valve actuators that regulate the distribution and quantity of air flowing from the leading and trailing edges.

Interconnecting springs between adjacent actuators permit indirect control of a disabled actuator to a position approximately midway between the adjacent actuators. Logic circuitry governs the operation of computers and valves according to the following criteria:

- Air blowing at the four stopped-rotor locations must be controlled by all four computers.
- Valves immediately adjacent to the stopped-rotor locations must be controlled by all four computers: this ensures that the stopped-rotor valves can be controlled by interconnected springs in case of an actuator or dual-computer failure at any of the stopped-rotor locations.
- No two computer failures shall result in loss of two adjacent valves or two of three adjacent valves.
- The effects of two computer failures, in any combination, must be distributed among an equal number of equally spaced valves.

Each valve is controlled by one of six computer combinations — AB, CD, AC, BC, AD, or BD. The 6 allowable failure patterns are distributed around the 24 valves on the leading edges and the 24 on the trailing edges (see figure). If the pattern begins at one of the stopped-rotor blowing-control actuators, criterion 1 is met.



This **Valve-Control-Redundancy Scheme** ensures that the effects of failure are distributed and that rotor control can be maintained. The X's indicate which valves would be disabled by a given combination of computer failures. For example, if computers A and D were to fail simultaneously, only trailing-edge valve actuators 5, 11, 17, and 23 and leading-edge valve actuators 3, 9, 15, and 21 would not be under direct control.

This work was done by R. Johnson, Jr., B. Trustee, and W. Fischer of United Technologies Corp. for **Ames Research Center**. *No further documentation is available. ARC-11531*

Portable Speech Synthesizer

A compact speech synthesizer can be a useful traveling companion to the speech-handicapped.

Ames Research Center, Moffett Field, California

Mute and other people with speech impairments can communicate better thanks to a portable speech synthesizer. A user simply enters a statement on a keyboard, and the synthesizer converts the statement into spoken words. Battery-

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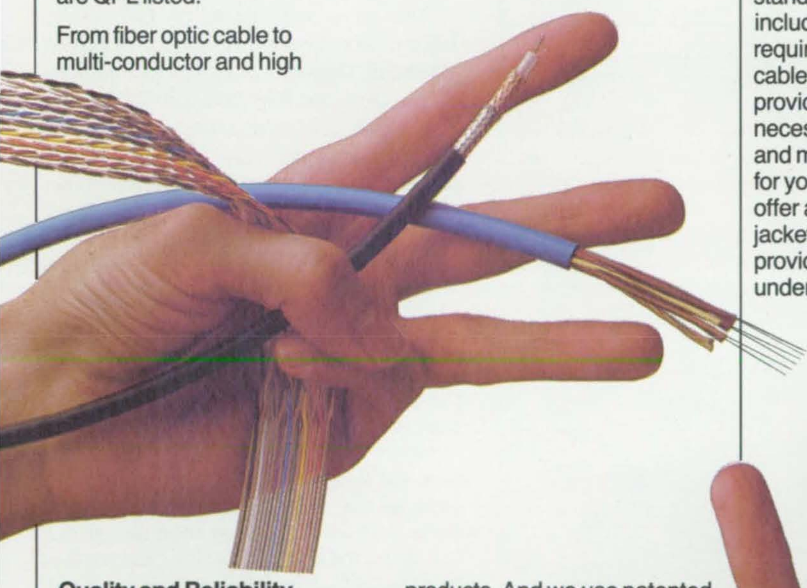

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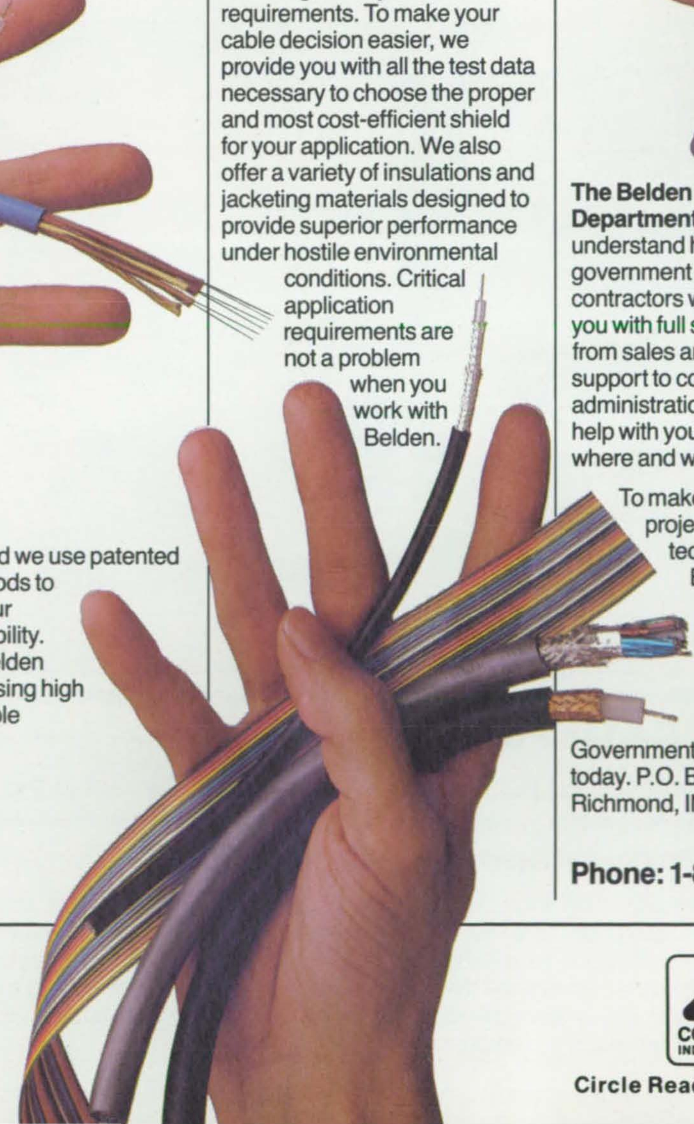

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Circle Reader Action No. 469

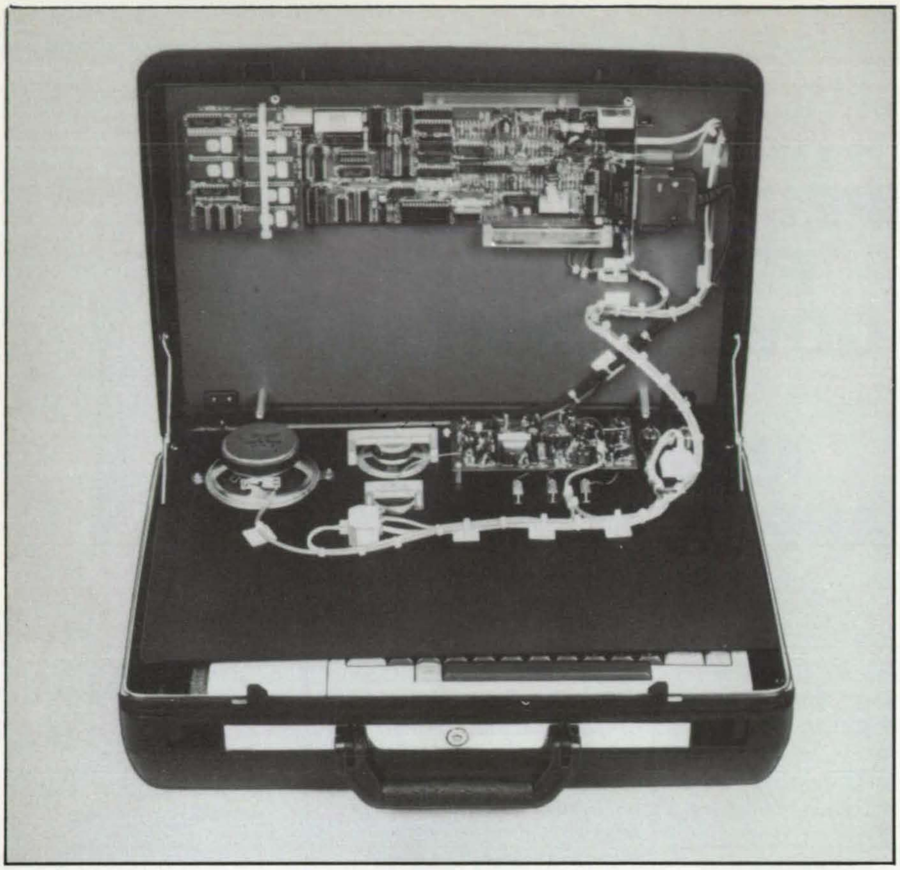
powered and housed in a briefcase, the synthesizer can be easily carried on trips and stows conveniently under an airplane seat. The unit can be used on telephones and in face-to-face communication.

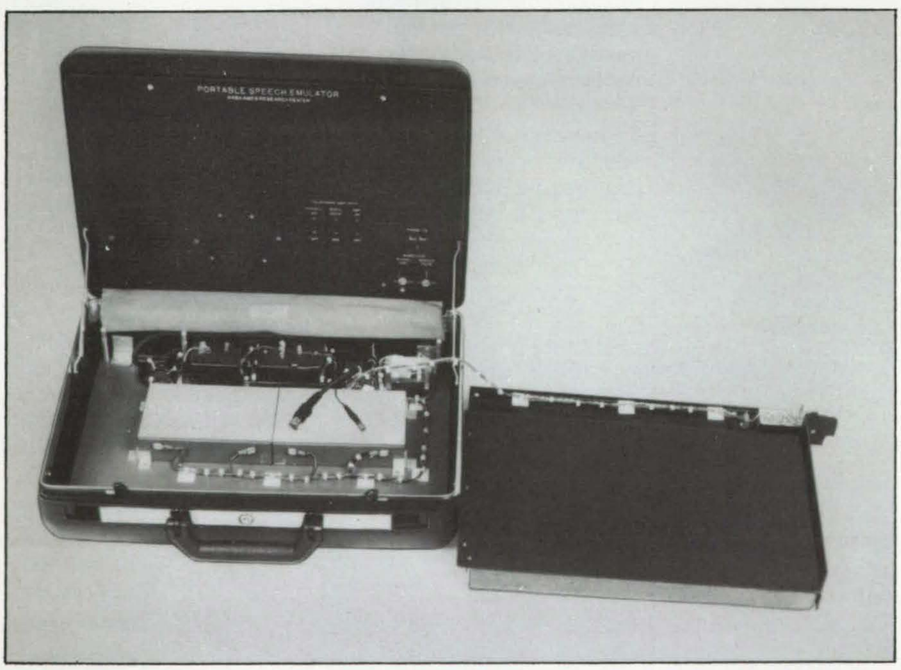
The synthesizer consists of a microcomputer with a memory-expansion module, a speech-synthesizer circuit, batteries, a recharger, a dc-to-dc converter, and a telephone amplifier. These components, all of which are commercially available, fit neatly in the 17- by 13- by 5-in. (43- by 33- by 13-cm) briefcase. The unit weighs about 20 lb (9 kg) and can be operated and recharged from an ac receptacle.

A user turns on the power and selects an appropriate text-to-speech program from the microcomputer menu. If the conversation is to be by telephone, the user first plugs a modular telephone jack in the unit into the phone. The user enters a statement on the keyboard, and the computer stores it in memory. When the user touches the return key, the computer converts the stored statement into speech. Commonly used phrases — for example, those used to begin telephone calls — can be included in the program and can be activated by pressing single keys.

This work was done by Gilbert H. Leibfritz and Howard K. Larson of **Ames Research Center**. *For further information, Circle 79 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center *[see page 14].* *Refer to ARC-11595.*





The Circuit Boards of the speech synthesizer and the telephone amplifier and its speakers and microphone are located behind the panel of the lid of the attache' case, as are all of the controls for those items and the telephone modular jacks. Located in the lower part of the case are the batteries, which are covered by a panel on top of which is the space for the microcomputer and the necessary cables. The microcomputer is removable so that it can be used for normal computations.

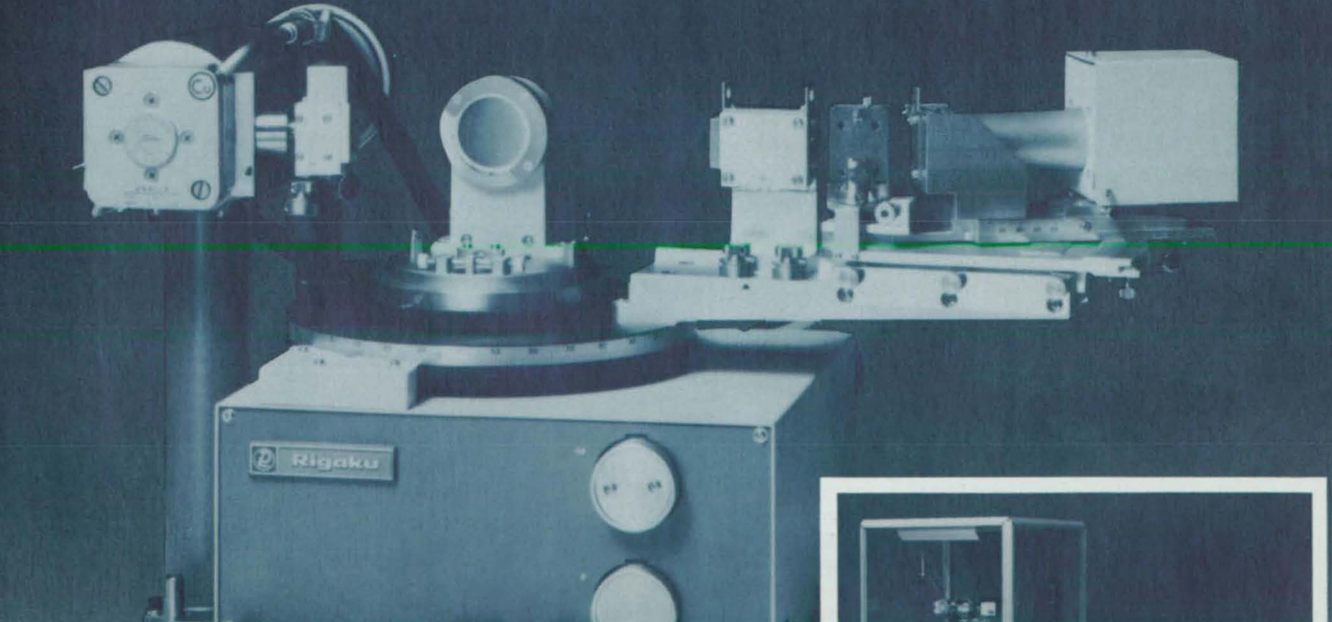
Imaging Radar Polarimeter

Radar measures the full polarization tensor of each element in the scene in one sweep.

NASA's Jet Propulsion Laboratory, Pasadena, California

By alternately transmitting horizontally and vertically polarized pulses (see figure) and recording the backscatter received in both polarizations in one pass over the terrain, an imaging-radar polarimeter collects all the information necessary to compute the full polarization tensor of each scene element. The antenna on a conventional imaging radar transmits and receives only one polarization component, making it impossible to obtain the full polarizaiton data in one pass.

The new system comprises a dual-polarized antenna, a single transmitter, and a four-channel receiver and digital recorder installed in an aircraft, plus a digital processor on the ground. This system produces radar-backscatter images corresponding



D/Max-B Wide Angle Diffraction System

to 10- by 10-km regions on the ground. A resolution of 10 m in the across-track direction is achieved by transmitting a pulse of 18-MHz bandwidth. In the along-track direction, a resolution of 3 m, one look (12 m, four looks) is obtained by the synthetic-aperture technique.

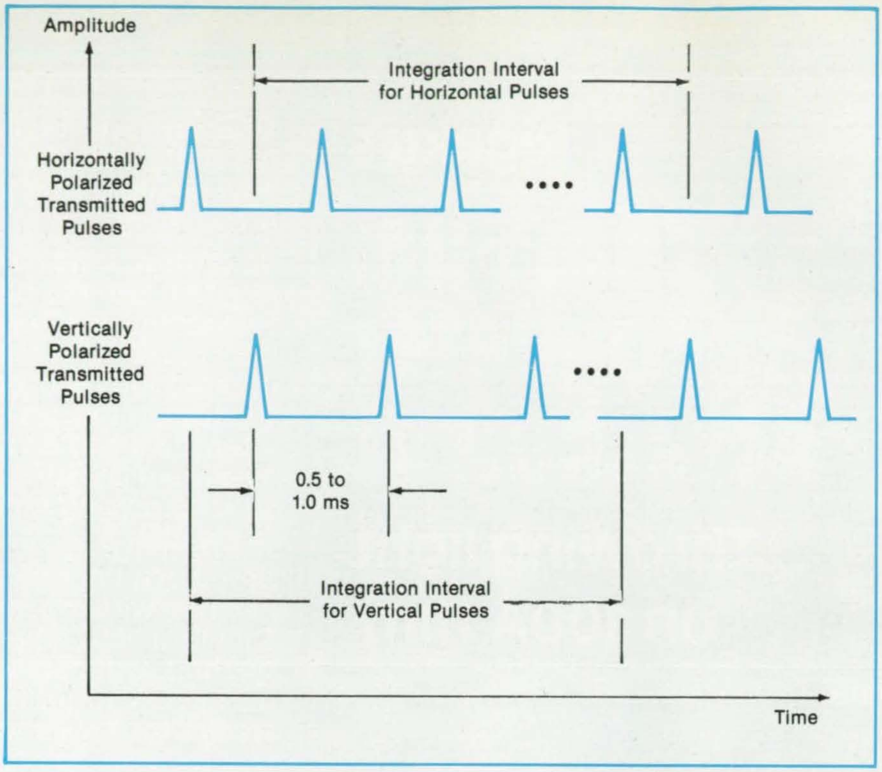
With the new radar, the signals recorded from orthogonal linearly polarized antennas are combined in a computer after the flight to synthesize any desired combination of transmitted and received polarizations. The data recorded on a single flight can be processed to provide multiple images, each representing the backscattered energy from the scene for a different combination of observational polarizations. A study of the polarization images can indicate the optimum choice of polarization representation for the observation of particular classes of objects and can provide insight into the dominant scattering mechanisms for each kind of object, thus improving the ability to identify correctly objects seen in the radar images.

The scattering matrix, S, contains the polarization information about the scene element in question. If a radar signal is transmitted with a polarization vector $\mathbf{C}_t$ and the target return is received with the antenna set to a polarization vector $\mathbf{C}_r$, then the voltage, V, at the receiver terminal is given by

$$V \propto C_{rx}(S_{xx}C_{tx} + S_{xy}C_{ty}) + C_{ry}(S_{yx}C_{tx} + S_{yy}C_{ty})$$

where x and y denote the horizontal and vertical components, respectively. If, for example, the signal is transmitted with horizontal polarization ($C_{tx} = 1, C_{ty} = 0$) and received with vertical polarization ($C_{rx} = 0$, $C_{ry} = 1$), then the received signal is proportional to S_{yx}. Similarly, the other elements of the scattering matrix are found by transmitting and receiving in various combinations of horizontal and vertical polarization.

This work was done by Howard A. Zebker, Daniel N. Held, and Walter E. Brown of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 89 on the TSP Request Card. NPO-16875*



The **Imaging Radar Polarimeter** alternately transmits horizontally and vertically polarized pulses at intervals of 0.5 to 1.0 ms. A synthetic aperture is formed by coherent integration over approximately 1,500 pulses of each transmitted polarization. Four separate integrations are done, one for each possible combination of horizontal and vertical transmitted and received polarizations.

New Products

More memory has been added to **Logical Device**'s (Fort Lauderdale, FL) EPROM programmer, the Shooter. Operating with a 256-bit (32K x 8) internal RAM buffer, or an optional 512K-bit (64 x 8) buffer, the unit programs, copies and verifies EPROMS from 2716 thru 27512 including CMOS and "A" version EEPROMs. The programmer interfaces via an IEEE RS-232 port, uploads/downloads standard file formats and uses fast, intelligent algorithms. Built-in debug firmware enables RAM editing and display with a terminal. **Circle Reader Action Number 589.**

To keep Subminiature-D connector pins straight, **Positronic Industries** (Springfield, MO) offers their Blindmate-D Guide System, which aligns the mounting flange for the free connectors with the floating panel islets of the fixed or panel mounted connectors. The system assures easy coupling and prevents damage to contacts through misalignment, providing circuit integrity during 500 operations. **Circle Reader Action Number 596.**

Artificial intelligence systems have the potential to provide increased efficiency in everything from data processing to manufacturing. To make AI technology more practical and accessible to mainstream corporate computing, **Gold Hill Computers Inc.**, (Cambridge, MA) has developed Golden Connection, a software product that allows developers to build PC-based expert systems that access corporate databases. Golden Connection provides the MV/Family of superminicomputers and the INFOS database with an interface to Gold Hill's expert system building tool—GoldWorks. The new interface is available from Data General, with whom Gold Hill has recently signed a joint development and marketing agreement. **Circle Reader Action Number 578.**

Sequent Computer Systems, in Portland, OR, has added the Sequent B8 to its Balance family of parallel computers. Incorporating high-density ESCSI disk drives, the B8 provides a single cabinet solution to departmental computing for 16 to 32 users. With expansion cabinets the system can support over 100 users. The system can support up to 450 MB of data storage in the main system cabinet, and the computer uses up to 12 32-bit NS32032 CPUs with an aggregate computing power of 8 MIPS. Up to 96 users can connect to the system over asynchronous lines. Additional connections to the system are supported through an X.25 interface. **Circle Reader Action Number 577.**

Twinax transmission cable from **Belden Wire and Cable** (Richmond, IN) can substitute for several multiple cables, increasing data load capacity while reducing size and weight. Belden 81553 offers excellent shielding against electrostatic and outside interference. The cable is designed for the MIL-STD-1553 Data Bus, which permits a single transmission cable (77 ohm twinax) to be used in 1 MHz multiplex computerized data distribution systems for command, control, communications and intelligence in aircraft, as well as other military and aerospace vehicles. Temperature rating is 200°C. **Circle Reader Action Number 594.**

Physical Sciences

Coma-Compensated Telescope With Vertex Chopping

Field-independent coma is cancelled with field-dependent coma.

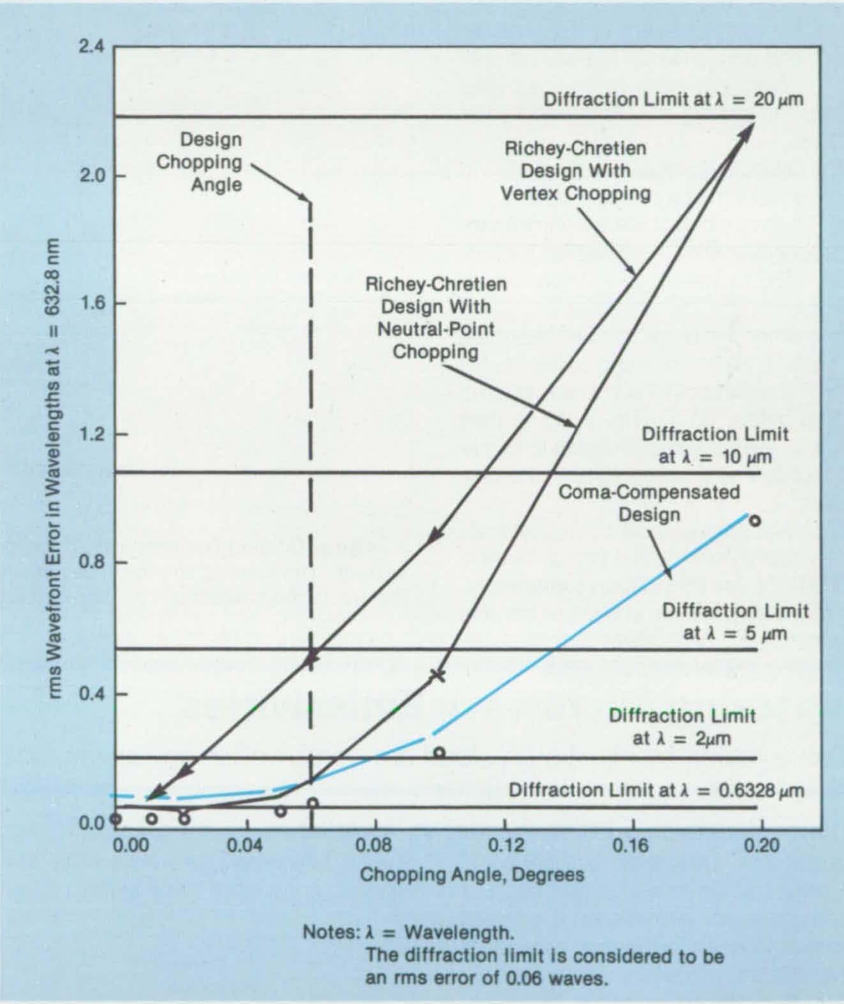
Ames Research Center, Moffett Field, California

A new design for a chopped-infrared astronomical telescope reduces coma to increase image quality. The light in such a telescope is chopped for signal-processing purposes — usually by repeated tilting of the secondary mirror about its vertex. This chopping introduces coma, which degrades the resolving power. In the new design, the coma introduced by tilting is cancelled by the shaping of the secondary mirror to introduce an equal but opposite amount of coma independent of the tilt angle. Because of this measure, the telescope performance on its axis remains limited mainly by diffraction (see figure).

In the chopping operation, the telescope aims alternately at a star and at an adjacent starless background region. The chopping-frequency signal corresponds to the star signal so that the more-slowly-varying background and detector noise can be subtracted out.

Ordinarily, an optical imaging system is optimized to provide high image quality over an area in the image plane for one fixed set of positions of the optical elements. Because the new telescope has only one detector on the axis, the off-axis image quality does not have to be optimized. Instead, the on-axis image quality is optimized over a range of secondary-mirror tilt or chopping angles so that the star image and the background region included with it are both made as small as possible to maximize the signal-to-noise ratio.

At the detector position on the instrument axis, one part of the coma due to chopping is proportional to the chopping angle and depends on the conic constant of the secondary mirror (which has a hyperbolic surface). The chopping changes the field (boresight) angle at which the detector is looking by an amount proportional to the tilt angle but independent of the conic constant of the secondary mirror. Yet another portion of coma depends on the field angle and the conic constant but does not depend on the chopping angle.



A **Coma-Compensated Telescope** with vertex chopping will provide diffraction-limited performance on its axis over a wider range of chopping angles than will either of the two previous designs, the performances of which are shown here for comparison. Each horizontal line shows how much wavefront error can be tolerated at its designated wavelength, while retaining diffraction-limited performance at longer wavelengths.

The new design exploits these relationships. The conic constant of the secondary mirror is selected so that, for any chopping angle, the field-dependent portion of coma at the designated boresight angle is the negative of the field-independent portion due to tilting. The shape of the primary mirror is then chosen to eliminate spherical aberration. The result is that on the instrument axis, the image is excellent over a wide range of chopping angles.

Defocusing due to field curvature sets the ultimate limit on the chopping angle. The field is quite flat up to that point; thus, little or no refocusing is required when the chopping-angle amplitude is changed.

This work was done by Malcolm J. MacFarlane of Perkin-Elmer Corp. for **Ames Research Center**. *For further information, Circle 45 on the TSP Request Card.* *ARC-11628*

Encapsulating X-Ray Detectors

A vapor-deposited polymer shields crystals from the environment while allowing x rays to pass.

NASA's Jet Propulsion Laboratory, Pasadena, California

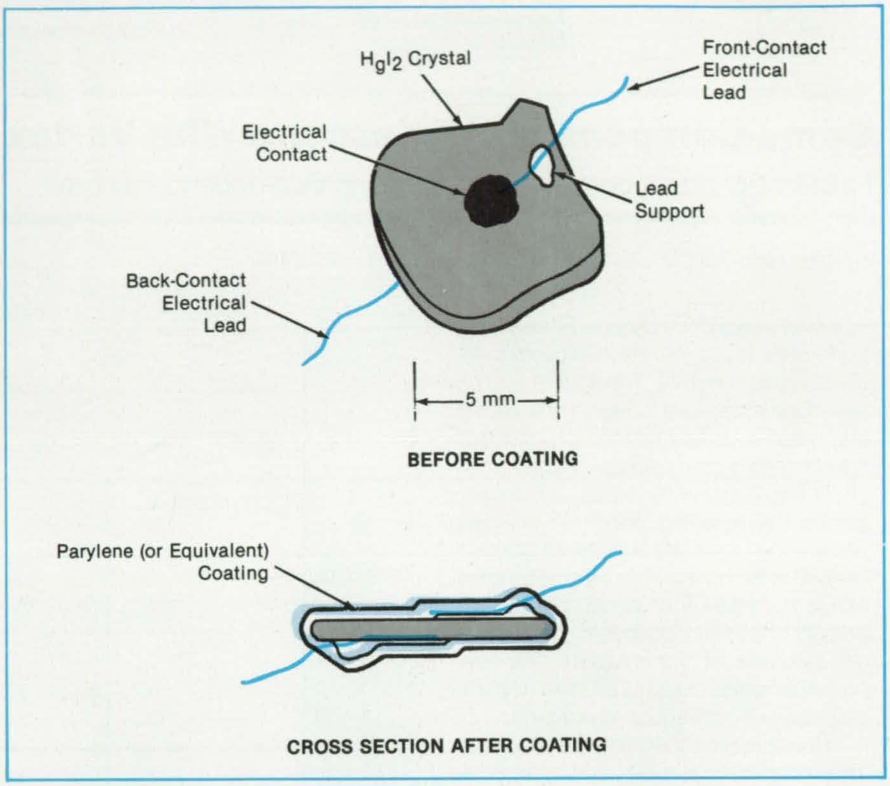
Fragile and chemically reactive mercuric iodide detectors for x rays can be protected over their entire surfaces by a vapor-deposition process. The process applies uniform layers of polymer in thicknesses ranging from 1 to 10 μm. The coating is transparent to x rays of energy greater than 1 keV.

After electrodes are attached to the HgI_2 crystal detector, the detector is transferred to a deposition chamber. There, successive layers of Parylene (or equivalent) condense on the crystal until the required thickness is attained (see figure). The coating is uniform and free of pinholes.

The deposition process is conducted in a partial vacuum at a pressure up to 5 torr (700 Pa). In one part of the vacuum chamber, di-p-xylylene (or a derivative) is pyrolyzed at 550 °C, yielding a vapor containing radicals.

In another part of the vacuum chamber, the radicals polymerize and condense on the HgI_2 crystal or other substrate, which is cooled below 50 °C. The coating that results is relatively impermeable to gases and moisture and covers even sharp projections.

This work was done by Joseph M. Conley and James G. Bradley of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 1 on the TSP Request Card. NPO-16910*



A **Polymer Coating Transparent to X Rays** is applied to a mercuric iodide detector in a partial vacuum. The coating, the thickness of which is exaggerated in the cross section, protects the crystal from sublimation, chemical attack, and electrical degradation.

Measuring Microwave Emissivities

A Dicke radiometer and a cryoload are combined in emissivity determinations of mesh antennas.

Langley Research Center, Hampton, Virginia

Surface emissivity, important to know in the temperature range anticipated for space use, is difficult to measure for mesh antennas. A newly developed measuring apparatus and procedure present a solution to this problem and thus fill a technological void in the accurate determination of surface emissivities at microwave frequencies.

The apparatus, which is capable of measuring independently the electromagnetic emissivity and/or intrinsic losses of surfaces, comprises a radiometer, a horn antenna, a test section, and a cryogenically cooled matched load (cryoload). In the system shown in Figure 1, the radiometer is of the Dicke type with pulsed noise-injection feedback that has proven to be stable over very long periods of time. The cryoload is filled with liquid nitrogen. A paraboloidal reflector is desirable in order to avoid phase-front distortions. A flat-plate reflector is easier to install in most cases but needs critical adjustment within the system.

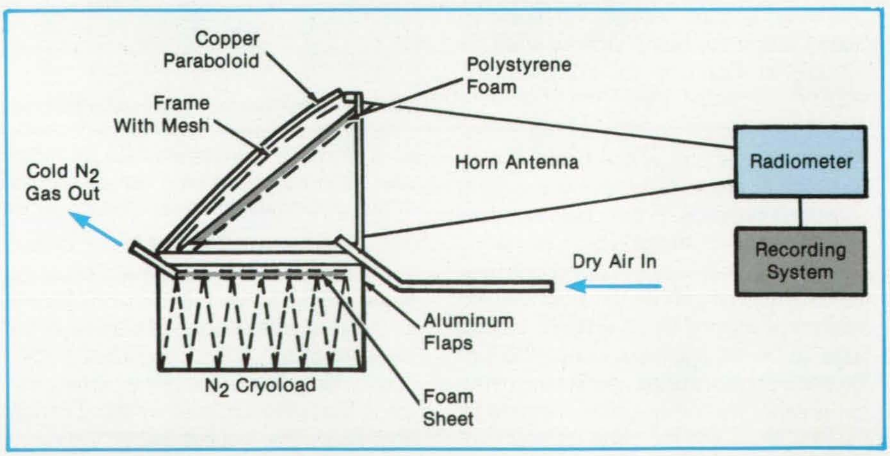


Figure 1. An **Ultrasensitive, Stable Radiometer** is used to measure very small emissivities with temperature changes with high resolution.

Derived from Plank's radiation law, the value of the surface emissivity of the mesh sample, in the microwave region up to 100 GHz, is given by

$$\varepsilon = (T_{B2} - T_{B1})/(T_{M2} - T_{M1})$$

where T_B is the radiometer brightness temperature, T_M is the physical temperature of the mesh sample, and 1 and 2 denote different temperature levels.

An example of the results of the measurement of a mesh-membrane sample is shown in Figure 2. T_B and T_M are shown in relation to one another and to the temperature changes that were produced by heater elements. Using this test apparatus and the above equation, the emissivity of the mesh sample was determined to be 0.01855. The intrinsic loss was 0.0811 dB. These measurements were conducted at 2.65 GHz with a radiometer integration time of 22 seconds and a brightness-temperature resolution of 0.02K.

This work was done by Hans-Juergen C. Blume of **Langley Research Center**. *For further information, Circle 111 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 14]. Refer to LAR-13455

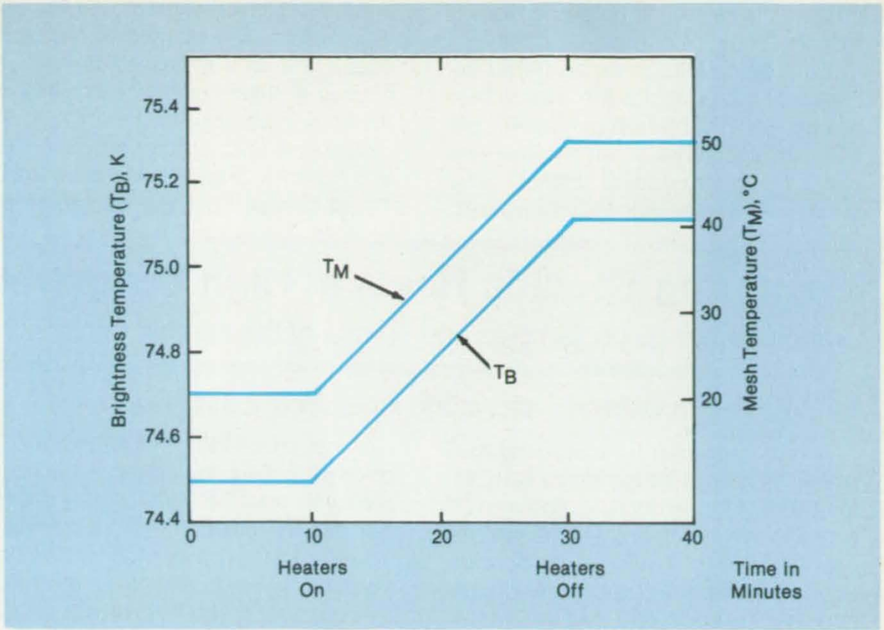


Figure 2. The **Temperatures of a Mesh Antenna** are used to calculate the surface emissivity in the microwave frequency range.

Compensating for Electro-Osmosis in Electrophoresis

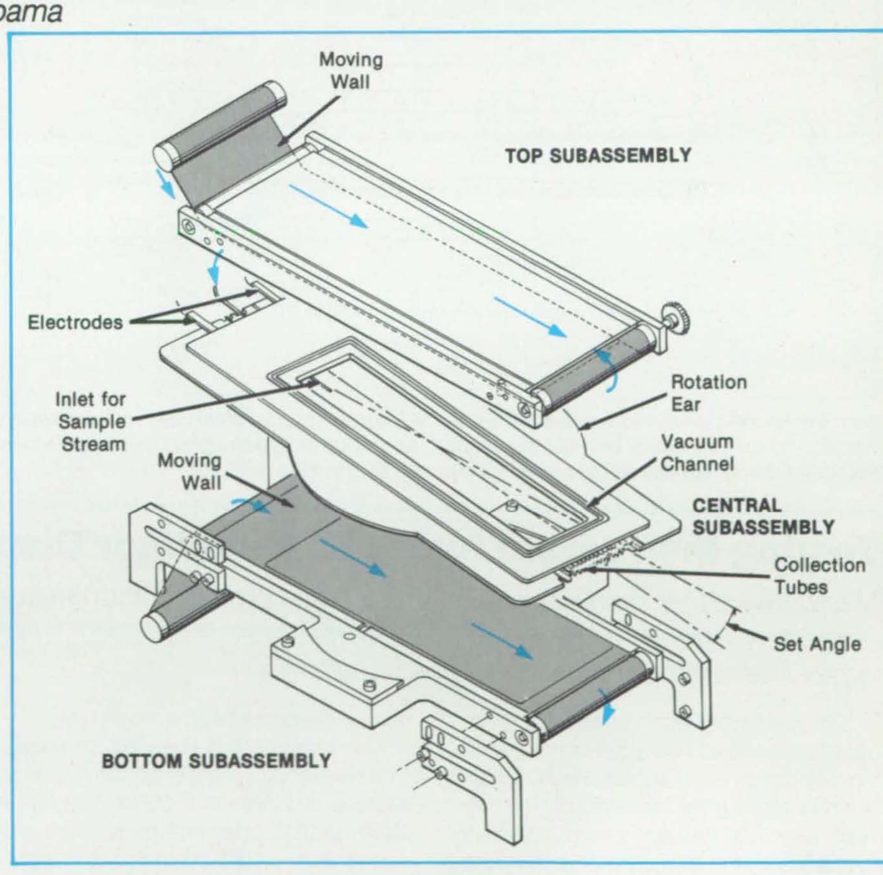
A simple mechanical adjustment eliminates a transverse velocity component.

Marshall Space Flight Center, Alabama

A new apparatus for moving-wall electrophoresis increases the degree of collimation of the chemical species in a sample stream. The apparatus compensates for electro-osmosis, which would otherwise tend to disturb the collimation.

Like other moving-wall electrophoresis devices, the apparatus eliminates the parabolic velocity profile in the stream by entraining a buffer liquid to flow as a rigid body. Unlike others, however, it does not include a wall coating of a zero-ζ-potential material to prevent distortion by electro-osmotic flow. Such coatings tend to lose their effectiveness quickly because they become contaminated by the sample and are damaged by the rollers and gaskets that make contact with the moving wall. Instead, the apparatus creates a component of transverse buffer-flow velocity that exactly opposes the transverse velocity produced by electro-osmosis.

The apparatus consists of three major subassemblies (see figure). The upper moving wall is a film that is unwound from one roller and taken up on another roller in the upper subassembly. Channels provide a slight vacuum that keeps the moving film in close contact with the inner surface. The electrophoresis chamber is in the central subassembly; it allows the insertion of the buffer and sample solutions. Two side electrodes protrude from one end of this subas-



The **Electrophoresis Chamber Is Set at a Slight Angle** in the horizontal plane to adjust the angle between the solution flow and the wall motion. The component of velocity thus created cancels the electro-osmotic effect.

sembly, and an array of collection tubes is mounted at the other end.

Semicircular ears on the central subassembly fit into guides on the lower subassembly, which contains a moving wall like that in the upper subassembly. The ears permit the electrophoresis chamber to be set at an angle relative to the moving films, and thus to provide compensation for electro-osmosis. The tangent of the angle equals the ratio of the electro-osmotic velocity at the moving wall to the buffer flowthrough velocity.

This work was done by Percy H. Rhodes and Robert S. Snyder of **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 14]. Refer to MFS-28142.

Measuring Specific Heats at High Temperatures

Graphite coatings on samples and control of the sample position increase accuracy.

NASA's Jet Propulsion Laboratory, Pasadena, California

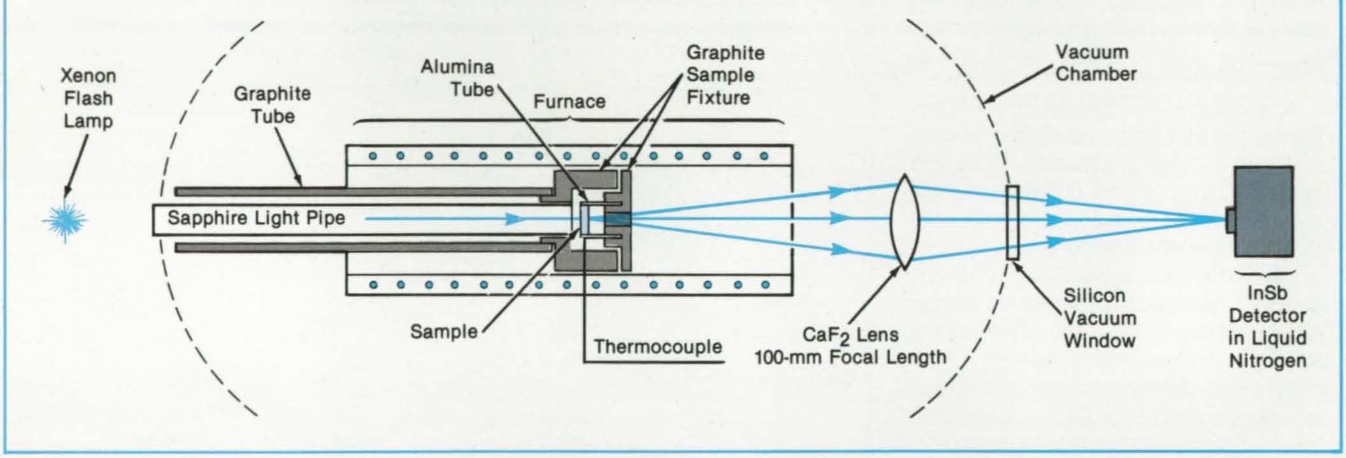
A flash apparatus for measuring thermal diffusivities at temperatures from 300 to 1,000 °C has been modified so that it can measure the specific heats of the samples to an accuracy of 4 to 5 percent. Specific-heat measurements on the modified apparatus are more accurate than those taken by differential scanning calorimetry and are more convenient to perform than drop calorimetry.

For the specific-heat measurements, the sample holder was modified so that the side of the sample that faces the flash unit is always in the same place, regardless of sample thickness. To make the sample absorptance a simple function of temperature and independent of the sample composition, a 300-Å thick layer of graphite is sputtered onto the front surface of each sample. The oven and sample temperature is determined with a type S (platinum/platinum, 10 percent rhodium) thermocouple in contact with the sample.

The apparatus was calibrated with reference samples of molybdenum, nickel, and graphite, the specific heats of which are known as functions of temperature. At a given thermocouple temperature, the radiant energy absorbed by each reference sample is determined from the temperature rise as measured by a calibrated InSb detector, which is focused on the back surface of the sample (also sputtered with graphite).

Similar measurements are then performed on a sample of unknown specific heat. The specific heat at a given temperature is calculated by dividing the radiant energy absorbed at the given thermocouple temperature by the product of the mass of the sample and the temperature rise measured by the InSb detector.

This work was done by Jan W. Vandersande, Andrew Zoltan, and Charles Wood of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 6 on the TSP Request Card.*
NPO-16765



Both the **Specific Heat and Thermal Diffusivity** of a sample can be measured with the apparatus shown. The xenon flash emits a pulse of radiation, which is absorbed by a sputtered graphite coating on the sample. The sample temperature is measured with the thermocouple, and the temperature rise due to the pulse is measured by the InSb detector.

Testing Instrument for Flight-Simulator Displays

Many devices for many diverse functions are combined in one equipment item.

Ames Research Center, Moffett Field, California

Displays for flight-training simulators are rapidly aligned with the aid of an integrated optical instrument. Calibrations and tests such as aligning the boresight of a display with respect to the user's eyes, checking and adjusting the display horizon, checking image sharpness, measuring the illuminance of displayed scenes, and measuring the distance of the optical focus of a scene can be performed with a single unit.

The instrument is intended for simulators in which a pilot sits in a cockpit as in an airplane and looks at a display that represents, in both color and perspective, the scene that would surround the plane. Lenses and other optical elements between the pilot and a cathode-ray-tube (CRT) display make the scene appear realistically distant.

Previously, many pieces of equipment had to be used for calibrations and tests. Each instrument had to be carefully positioned at the design eyepoint (DEP) — the locus of points at which a pilot's eyes are likely to be during simulator flight for looking out of cockpit windows and watching the instrument panel. The difficulty was

compounded because flight-training simulators usually had more than just one scene display; most had at least four, and it was necessary to reposition each test device for each display. Clearly, this was a time-consuming procedure and prone to measurement error.

The new instrument, in contrast, combines all measurement devices in a single, compact, integrated unit. It requires just one initial setup. It employs a laser instead of an incoherent light source and thus produces a narrow, collimated beam for greater measurement accuracy. To improve accuracy further, it uses only one moving part, a double right prism, to position the laser beam.

The key components of the instrument are as follows:

1. A low-power helium/neon laser
2. A glass, double right prism mounted on a rotatable base with a thumb-lock knob — Angular accuracy up to 0.25° is possible. The center of rotation is positioned at the DEP in the cockpit or laboratory so that only the prism need be rotated to project the laser beam in various directions across the horizontal meridian. The prism serves as a beam splitter that enables the observer to look safely along the laser beam to evaluate the display-system optical performance, as indicated by the displacement, reflection, and refraction of the beam.
3. An aperture plate — Small-diameter apertures are located between the laser and the double right prism so that the beam size can be varied.
4. A y-z-adjustable microscope stage — This support stage permits the aperture plate to be moved precisely in the y (horizontal, perpendicular to the laser beam) and z (vertical) directions to center the aperture over the laser beam. The stage also holds a variety of clear and frosted lenses, which may be used to spread the laser beam.
5. A neutral-density wedge filter — Located between the laser and the aperture plate, this filter can be slid to any position in a slot to increase or decrease the beam intensity.
6. A viewing eyepiece — The eyepiece lens has a relatively large exit pupil of 0.87 in. (2.2 cm) in diameter. It has a spring-loaded tie-down strap.
7. A telescope objective lens — Used with the eyepiece lens, the telescope objective is 2 in. (5.1 cm) in diameter and has an effective focal length of about 11 in. (27.9 cm). It is focused by an adjusting screw.
8. An illuminometer — This battery-powered device rests on an aluminum bracket that permits its photosensitive head to be rotated into position in place of the human observer's eye behind the eyepiece.
9. A base — A plate made of rigid aluminum with threaded holes and lightening holes supports the instrument components.
10. Legs — Four collapsible metal legs allow the unit to be placed securely on a horizontal or tilted surface.
11. A dioptometer — This is an optical rangefinder similar to the eyepiece in size and shape. It is mounted in place of the eyepiece and used to find the effective optical distance of the scene from the design eyepoint.

This work was done by Richard F. Haines of **Ames Research Center.** *For further information, Circle 137 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center *[see page 14].* *Refer to ARC-11504.*

Analyzing Nonisothermal Crystallization of Thermoplastics

Polycrystallinity is observed at different, but constant, heating rates.

NASA's Jet Propulsion Laboratory, Pasadena California

A method has been developed for the analysis of nonisothermal cold crystallization in thermoplastics. Unlike previous methods, this does not require prior knowledge of the isothermal kinetic parameters. The approach is based upon the observation that, during nonisothermal crystallization at a constant rate, the relative crystallinity develops with a time dependence that is sigmoidal at low degrees of conversion. A likely application for this method is in the study of cold crystallization in advanced thermoplastics.

The method involves fitting the time dependence of the relative crystallinity, a, to an equation of the form $\ln(1-a) = Kt^n$, where $0<a<1$ and t = time. The parameters K and n are determined at each heating rate from a plot of $\log[-\ln(1-a)]$ versus $\log t$.

The rate parameter K can be expressed approximately by $K^{1/n} = K_0\exp(-E/RT)$, where E = the activation energy, R = the ideal-gas constant, and T = the absolute temperature. This equation is evaluated at temperatures that correspond to a fixed degree of conversion.

In an application of the method, cold-crystallization data were obtained for poly (etheretherketone), PEEK, by cooling it at different, but constant, rates (from 1 to 50 °C/min) in a scanning calorimeter. The activation energy of the primary crystallization process was 52 kcal/mole. The nonisothermal cold crystallization resulted in a degree of crystallinity between 20 and 25 percent. A large percent of this crystallinity was developed by secondary kinetic processes. The main endothermic response occurred at 335 °C, regardless of the crystallization heating rate. A small secondary endotherm appeared just above the original crystallization exotherm temperature: this annealing peak represents the melting of a small fraction of unstable crystals formed during the nonisothermal crystallization.

This work was done by Peggy Cebe of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 20 on the TSP Request Card.*
NPO-16866

Materials

Crystal Growth in Liquid-Encapsulated Float Zone

Liquid surrounding the melt prevents evaporation, suppresses convection, and supports the melt.

Marshall Space Flight Center, Alabama

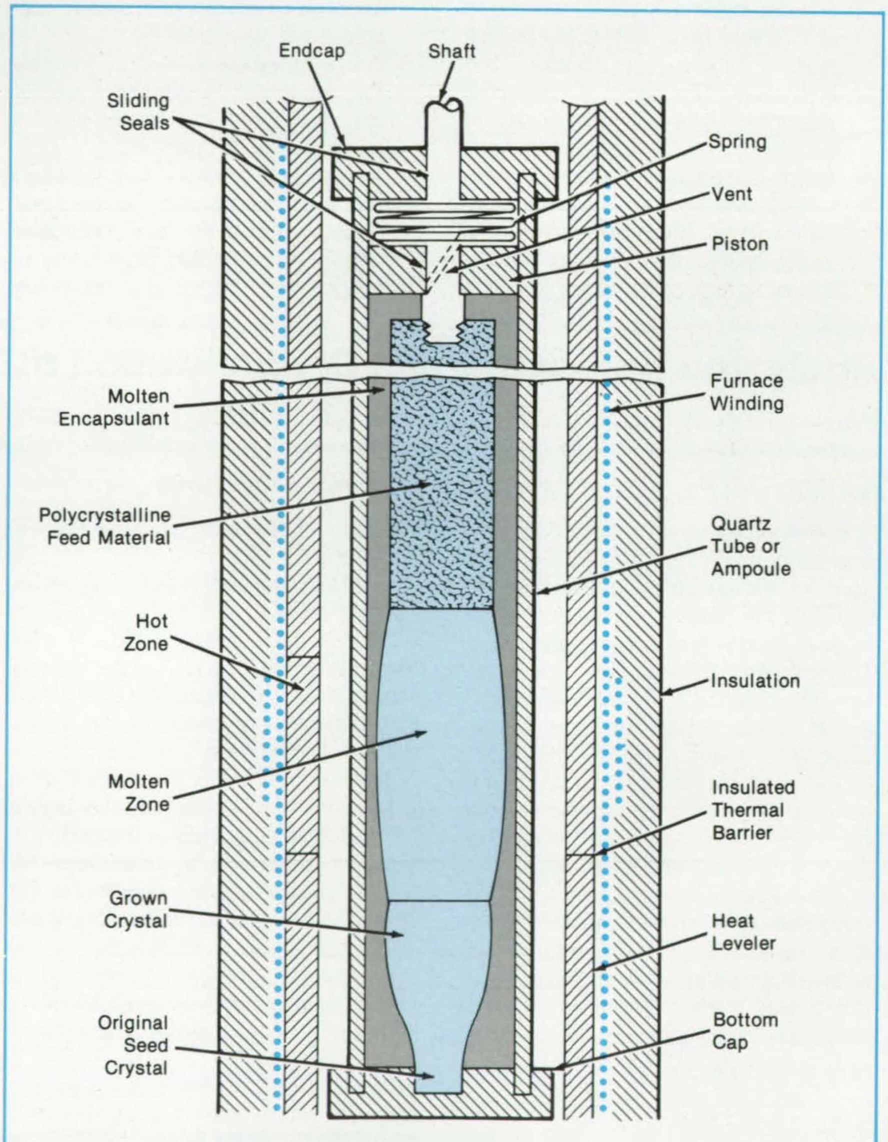
A suitably chosen liquid encapsulant placed around the melt zone in a float-zone crystal-growth system (see figure) can perform four important functions that enhance purity and reduce strains and dislocations in the final crystal. With the new technique, it should be possible to grow dislocation-free crystals with precisely controlled composition even from materials that are not amenable to the conventional float-zone crystal-growth method.

In the apparatus, the crystal is grown from a polycrystalline feed material. A single seed crystal of the desired orientation is attached at one end, as in conventional float-zone growth. The feed material is surrounded by the powdered encapsulating material contained in a quartz tube or ampoule, which can withstand the temperatures required to melt the crystalline material and which is wet by the molten encapsulant in preference to the molten feed material.

A spring-loaded piston allows for thermal expansion and contraction and maintains the materials under a pressure equal to or greater than the vapor pressure of the most volatile component at the highest temperature. During initial melting of the encapsulant, a vent allows gases trapped in the encapsulant to escape. Some liquid may escape, but eventually the piston moves inward and closes the vent.

The ampoule is placed so that the initial increase in the temperature of the hot zone melts the feed material adjacent to the seed. The ampoule is then translated to move the molten zone along the rod of feed material, as in conventional float-zone processing.

The encapsulant must have a melting temperature lower than that of the material to be crystallized and it must be almost completely immiscible with the melt in the liquid phase. The encapsulant must also be electrically inert; that is, it must not act as a dopant if the crystal is to be used for electronic devices. Examples of suitable encapsulants include B_2O_3 for GaAs and probably CaF_2 for Si and Ge.



The **Liquid-Encapsulated-Float-Zone Crystal-Growth Apparatus** fits in a muffle furnace with an independently controlled hot zone.

One function of the encapsulant is to prevent the loss of relatively volatile components from the melt in such compound semiconductors as GaAs, GaAlAs, and CdTe and in organic and polymeric systems. The encapsulant also functions to

suppress surface-tension-driven convection, particularly if it is B_2O_3, which has a high viscosity.

The molten encapsulant functions as an easily deformable container that allows the crystal to expand or contract without inducing strains and defects. Many semiconductors expand on freezing; strains induced by the rigid containers required in some crystal-growth methods are thought to be an important cause of defect formation.

The molten encapsulant provides buoyancy support for the molten zone, thus reducing the effect of gravity on the system and allowing larger melt zones, and hence, crystals of larger diameter. A larger melt zone also enables better control of the thermal profile near the solidification interface. The support provided by the encapsulant may make it practical to process materials of low surface tension, such as organic and polymeric materials, which would otherwise be difficult to process in the presence of gravity.

This work was done by Robert J. Naumann, Donald O. Frazier, Sandor Lehoczky, Marcus Vlasse, and Barbara Facemire of **Marshall Space Flight Center**. *For further information, Circle 67 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 14]. Refer to MFS-28144.

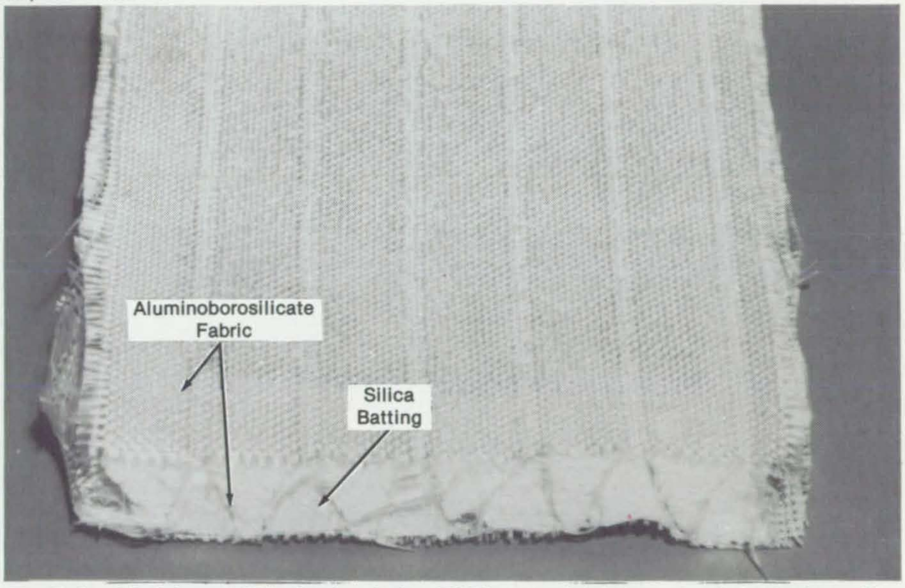
Tailorable Advanced Blanket Insulation (TABI)

An integral woven core of ceramic yarns holds silica batting for thermal protection of space vehicles.

Ames Research Center, Moffett Field, California

Both single layer and multilayer insulating blankets for high-temperature service can now be fabricated without sewing. The new blankets, called TABI, can be used at higher temperatures because the heat resistance of the sewing thread is no longer a limiting factor. Moreover, the blankets are no longer subject to damage and weakening by the sewing process. The blanket is smoother and its thickness more uniform, because it is no longer quilted by stitches.

The new TABI blanket consists of an integrally woven, filled core between two fabric faces. The faces and core can be woven from any of three ceramic yarns: silica, aluminoborosilicate, or silicon carbide. The core may be woven as hollow rectangular or triangular flutes and filled with silica-fiber batting (see figure). Alternate batting materials such as aluminoborosilicate or alumina could also be utilized. A double-layer core has also been woven, one layer filled with the silica batting and the other with rigid ceramic tile.



The **Tailorable Advanced Blanket Insulation (TABI)** woven fabric is made of aluminoborosilicate. The triangular-cross-section flutes of the core are filled with silica batting. The flexible blanket can be formed into curved shapes, providing high-temperature and high-heat-flux insulation.

The woven-core blankets can withstand substantially greater heat flux than can the older sewn silica blankets. For example, the woven aluminoborosilicate blanket can withstand as much as 7.5 Btu/ft^{2}s (85 kW/m^2), and the woven silicon carbide blanket can handle up to 30 Btu/ft^{2}s (340 kW/m^2). In contrast, the quilted silica-fiber fabric is limited to 4.4 Btu/ft^{2}s (50 kW/m^2).

This work was done by Paul M. Sawko and Howard E. Goldstein of **Ames Research Center**. *For further information, Circle 10 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel. Ames Research Center [see page 14]. Refer to ARC-11697.

Light, Strong Insulating Tiles

Experiments with composition yield a desirable combination of properties.

Lyndon B. Johnson Space Center, Houston, Texas

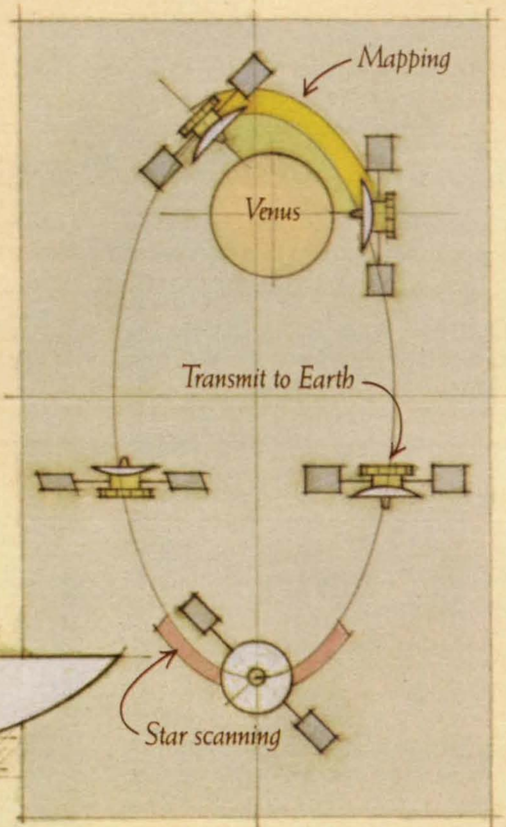
Improved lightweight insulating silica/aluminum borosilicate/silicon carbide tiles combine increased tensile strength with low thermal conductivity. The new tiles replace older all-silica tiles of approximately equal thermal conductivity and higher mass density.

As originally formulated, the new tiles were composed of silica and aluminum borosilicate fiber with 2 percent silicon carbide particles (as an emissivity-controlling agent) in 320-grit (about 41-μm) size. These tiles had lower density than their all-silica predecessors — 8 lb/ft^3 vs. 9 lb/ft^3 (128 kg/m^3 vs. 144 kg/m^3) as well as higher tensile strength. However, insulating properties were not adequate, the thermal conductivity being much higher than that of the all-silica tiles.

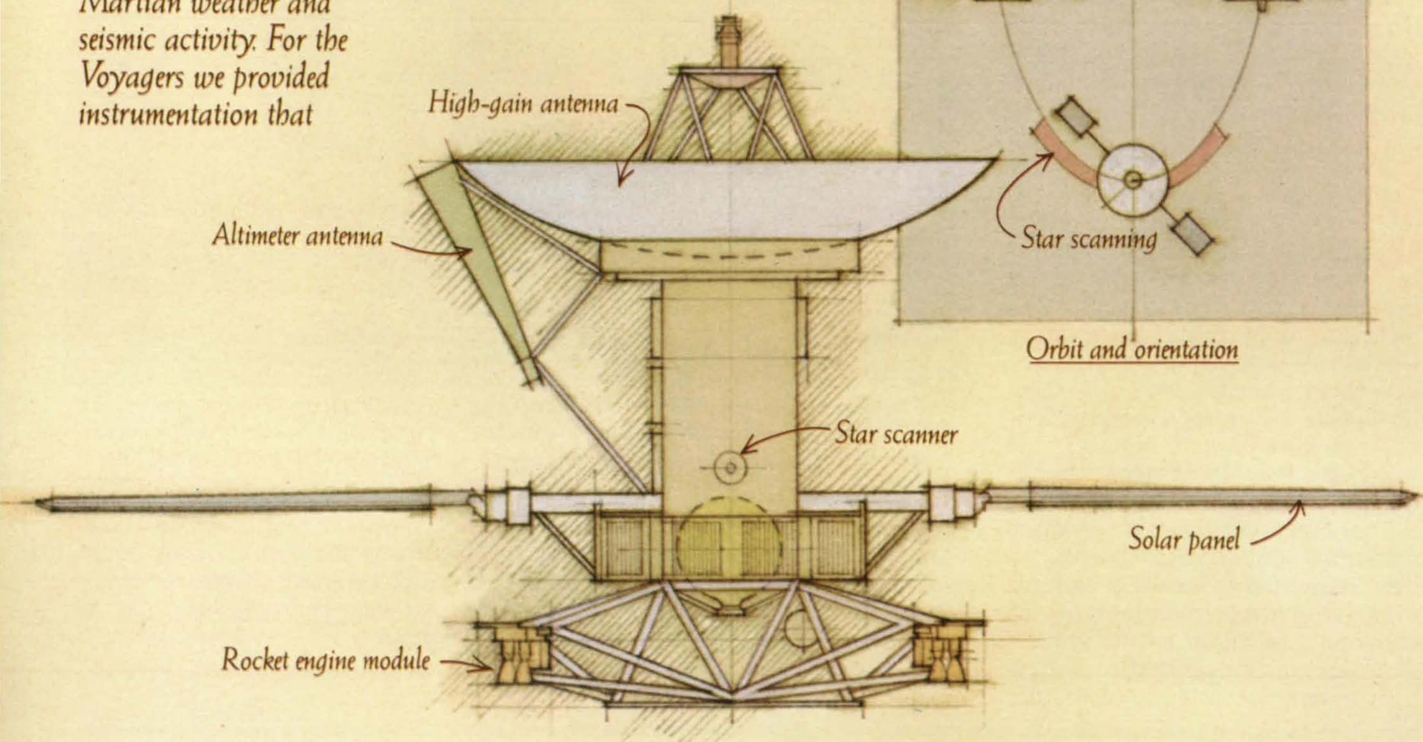
After some experimentation, a new formulation was found to reduce the thermal conductivity: the concentration of aluminum borosilicate fiber was reduced, the dry (unfired) density of the tile billets was increased, the proportion of silicon carbide was increased to 3 percent, and the silicon carbide particle size was reduced to 600

In space: looking back to look forward.

What can the nature and origin of the universe tell us about the future of Earth? To help answer that question, we make craft and instruments for traveling billions of miles in space and seeing as far as 15 billion years back in time. Martin Marietta was the integrator and builder of two Viking landers, which sent back remarkable photos of the surface of Mars, examined soil samples, and studied Martian weather and seismic activity. For the Voyagers we provided instrumentation that reported on electromagnetic activity near Jupiter and Saturn—Voyager 2 went on to Uranus, some 2 billion miles from Earth. That was nine years after launch; next destination, Neptune, in 1989. These are but a few results of Martin Marietta's ability to create survivable, mystery-solving craft and their instruments—from concept through mission completion.



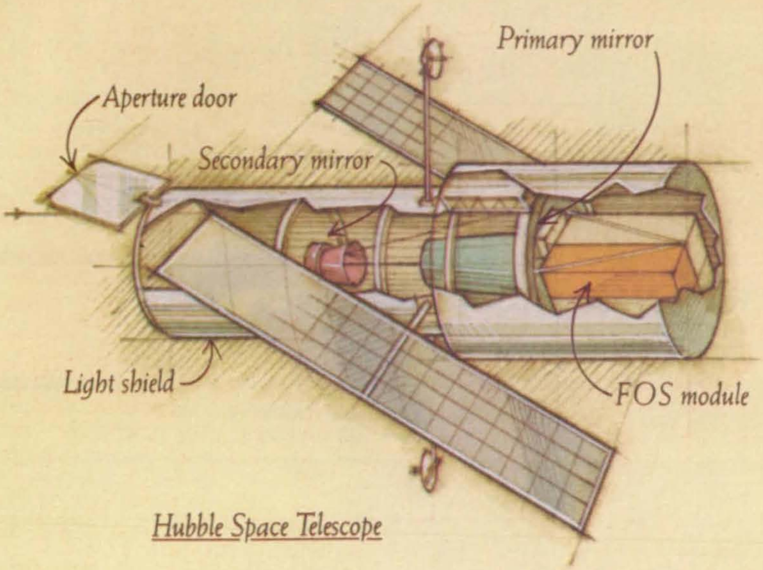
Orbit and orientation



Magellan Spacecraft

Mission: map Venus.

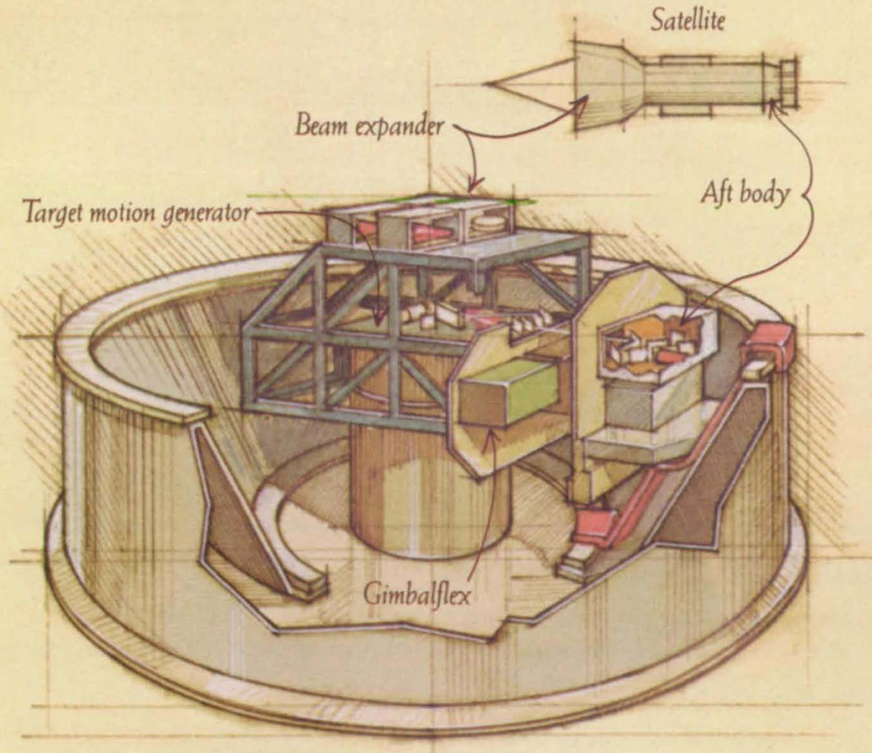
From orbit, Magellan's radar will penetrate the planet's thick, gaseous cloud cover and send back photo-like images of nearly 90% of its surface. Our role: design, integrate, build and test the craft.



Hubble Space Telescope

Viewing the infant universe.

For the Hubble Space Telescope we are providing the Faint Object Spectrograph (FOS), which will see objects up to 15 billion light-years away. Since the universe is estimated to be 18-20 billion years old, astronomers will witness events close to its birth.



Fine Pointing Simulator

The fine points of fine pointing.

Precisely controlled, space-spanning energy delivery and collection systems create difficult pointing and retargeting challenges, which we can now simulate. This new lab is working toward the precision to zero in on a football-size object 3,000 miles away, in support of the Strategic Defense Initiative research program.

Masterminding tomorrow's technologies

MARTIN MARIETTA

6801 Rockledge Drive, Bethesda, Maryland 20817, USA

grit (14 μm), as shown in the table. Although the density increased slightly with this formulation, it was still less than that of the all-silica tiles, and thermal conductivity was essentially the same as that of the all-silica tiles.

Apparently the smaller silicon carbide particles reduce the mean free path for thermal radiation, thereby increasing scattering in the material. Increasing the dry density and reducing the aluminum borosilicate fiber content have a similar effect.

This work was done by E. Cordia and J. Schirle of Lockheed Missiles & Space Co. for **Johnson Space Center**. *For further information, Circle 130 on the TSP Request Card. MSC-20601*

Material	SiC Grit Size/ Concentration (Percent by Weight)	Dry (Unfired) Density lb/ft^3 (kg/m^3)	Silica/Aluminum Borosilicate Fiber Ratio	Final Density lb/ft^3 (kg/m^3)	Effective Thermal Conductivity Relative to All-Silica
Original Composition	320/2	5.0 to 6.5 (80 to 104)	78/22	8.0 to 9.0 (128 to 144)	Much Higher
Improved Composition	600/3	7.0 (112)	85/15	8.5 (136)	Essentially Equivalent

Changes in Composition substantially improve the heat-insulating properties of silica-based refractory tile. The silicon carbide particles act as high-emissivity radiation scatterers in the tile material.

Paint-Bonding Improvement for 2219 Aluminum Alloy

Delaying a rinse step in a deoxidizing treatment improves bonding.

Marshall Space Flight Center, Alabama

The bonding of adhesives and primers to 2219 aluminum alloy is improved by delaying a rinse step in a surface-treatment process. Examinations of treated surfaces by stereo electron microscopy show that the addition of a delay between the application of Smutgo #1 (or equivalent) and the following water-rinse step causes an increase in the effective surface area.

Although the original process was the best commercially available, 2219 aluminum is difficult to bond, and 700 out of 1,700 parts treated in the standard manner failed an adhesion test. The failure rates for various types of parts ranged from 0 to 100 percent. The poor results obtained in the original treatment seem to be caused by carbon dioxide dissolved in the rinse water. Apparently, the carbon dioxide forms a carbonatelike reaction product with the aluminum or aluminum hydroxide. This reaction product terminates the reactivity of the surface prematurely, producing a relatively flat surface-oxide thickness.

Delaying the rinse allows the formation of a rougher surface for stronger bonding and a greater oxide buildup. Panels that are rinsed immediately are more sensitive to moisture and contamination. In tests of various rinse delays extending all the way to allowing the sample to dry before rinsing, the optimum rinse delay was found to be 10 to 15 min. Test results comparing the original and the modified treatments are shown in the table.

This work was done by Alfred F. Daech and Audrey Y. Cibula of Martin Marietta Corp. for **Marshall Space Flight Center**. *No further documentation is available. MFS-28166*

RESULTS FROM AUGER SPECTROSCOPY AND ELECTRON SPECTROSCOPY FOR CHEMICAL ANALYSIS

	Immediate Rinse	Rinse Delayed 10 Min
Surface Roughness	150 Å	250 Å
Sputter @ 10 Å/min	4.25 min	5.75 min
Oxide Thickness	42.5 Å	57.5 Å
Atomic % of Cu	0.8	1.1

PRIMER-ADHESION TESTS

Proportion of Demineralized Water to Smutgo (or Equivalent)	Wet-Tape Test		Elcometer (or Equivalent) Value, psi	
	Immediate Rinse	Rinse Delayed 10 min	Immediate Rinse	Rinse Delayed 10 min
50:1	Fail	Pass	400	1,300
100:1	Fail	Pass	750	1,450
200:1	Fail	Pass	1,800	1,900
500:1	Pass	Pass	>2,000	>2,000
1,000:1	Pass	Pass	>2,000	>2,000
2,000:1	Pass	Pass	>2,000	>2,000
Control	Pass	Pass	>2,000	>2,000

Increased Surface Roughness, Oxide Thickness, and Adhesion are exhibited by surfaces treated with a delayed rinse.

Clarification Procedure for Gels

Potassium-ion substitution in a silicate solution produces transparent gels.

Langley Research Center, Hampton, Virginia

When crystals are grown in gels, it is preferable that the gels be transparent enough to allow one to view the crystal growth. Typically, gels for crystal growth made by acidifying a stock sodium silicate solution according to standard laboratory technique are merely translucent. A procedure has been developed to obtain transparent gels with consistencies suitable for crystal growth, by replacing sodium ions in the silicate solution with potassium ions.

The clarification process uses a cation-exchange resin to replace sodium ions in the stock solution with potassium ions. The cation-exchange resin is placed in a 1 M solution of a soluble potassium salt, such as potassium nitrate or chloride. This slurry is stirred for several hours to allow the potassium ions to replace all other cations on the resin. The supernatant solution on the resin beads is decanted through a filter, and the beads are rinsed with distilled water. Rinsing removes the excess salt but leaves the cation-exchange beads fully charged with

potassium ions.

The pretreated cation-exchange resin beads are then transferred to the sodium silicate stock solution and stirred for several hours to allow the sodium ions in the solution to exchange with the potassium ions from the resin beads. The amounts of solutions and of resin beads used are not critical as long as enough quantities are used to limit the ion exchange only by the amount of sodium ions in the original stock solution. The stock solution is poured off through a coarse filter and used to prepare gels that are much more transparent than those made with untreated stock solution. The cation-exchange beads in the filter can be rinsed with distilled water and reused. In fact, they can be stored in the potassium salt solution.

It is recommended that the treated potassium silicate stock solution be mixed with cool, boiled (to remove dissolved gases from the water), distilled water and that the mix be acidified with acetic acid in the following proportions:

- 16 parts treated stock solution;
- 25 to 29 parts cool, boiled, distilled water; and
- 25 to 26 parts acetic acid solution (1M to 4M).

It is important that the components be mixed in the above order to yield clear, reproducible gels. The smaller volumes result in firm gels, while the larger volumes give softer gels. The more concentrated acid solutions cause the gel to set faster than do the weaker solutions. Individual experimentation is required to produce gels of the proper consistency and setting time for the desired application.

This work was done by Patrick G. Barber and Norman R. Simpson of Longwood College for **Langley Research Center**. *For further information, Circle 156 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 14]. Refer to LAR-13476

Localized Densification of Tile for Impact Resistance

Colloidal silica is applied, in controlled quantities, only where it is needed.

Lyndon B. Johnson Space Center, Houston, Texas

A densification process increases the impact resistance of lightweight, porous silica tile without appreciably raising its weight. The process is similar to one described in "Attaching Metal Fasteners to Silica Tiles" (MSC-20537), page 122, *NASA Tech Briefs*, Vol. 10, No. 1 (January/February 1986). A colloidal suspension of silica is used to increase the density of the small portion of the tile to be strengthened; the process controls the penetration of the suspension both laterally and vertically so that densification is limited to the volume where it is needed. This ensures that the weight is increased only minimally.

The tile is first waterproofed throughout with methyltrimethoxysilane. The surface of the portion to be strengthened is then exposed to radiant heat long enough to burn out the waterproofing to the intended depth below the surface. The tile will accept the densifying agent in the dewaterproofed region but not in the waterproofed region. The heating time is calculated from an equation that relates the surface temperature, as measured by a thermocouple, to the depth at which the tile temperature rises to 1,050 °F (566 °C), which is the temperature at which the waterproofing is destroyed.

Next, the tile is weighed. The weight gain that will yield the required density increase in the dewaterproofed region is calculated. The open volume of the total volume to be dewaterproofed is calculated from the known density of silica [137 lb/ft^3 (2,200

kg/m³)] and the measured density of the tile. A volume of colloidal silica suspension equal to this open volume is applied to the dewaterproofed surface.

The tile is dried in air for 24 hours, then heated in an oven at 110 °C for 1 hour. The tile is weighed, and its new weight is compared with the calculated weight gain for the requisite local increase in density. If the tile is underweight, the densification process is repeated.

This work was done by Laurence W. Smiser and Jack W. Holt of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 70 on the TSP Request Card.* MSC-20612

Making Highly Porous Ceramics

Freeze drying generates high porosity.

Lyndon B. Johnson Space Center, Houston, Texas

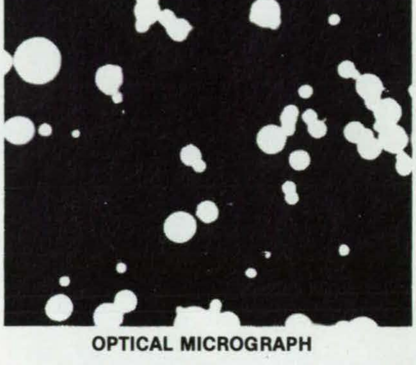
Rigid, lightweight insulation that can withstand temperatures greater than 1,400 °C is made by a cryogenic freeze-drying process. When fully developed, the new insulation is expected to have a solid content as low as 1 percent by volume and to be mechanically isotropic. Insulation made from silica fibers, in contrast, has a lower temperature limit and is weaker in certain directions because of the anisotropy introduced by the fibrous microstructure.

In an experiment, sodium carbonate in water and aluminum sulfate in water were mixed with more water to form a solution containing 94 percent water by volume. (The water content is important because it controls the solid content in the finished product.) The slurry was sprayed into liquid nitrogen, where it froze so rapidly that the components were prevented from segregating. The solids thus formed had a uniformly fine microstructure.

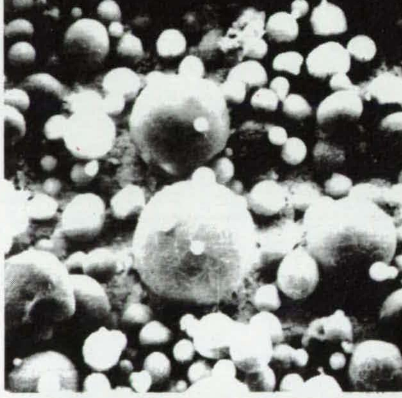
The frozen solids were placed in a vacuum chamber. The ice evaporated, leaving a powder of porous particles (see figure). The powder was poured into a mold, uniaxially pressed, and sintered at 1,475 to 1,600 °C. The product was a rigid alumina ceramic of greater than 90 percent porosity. The product resisted attempts to increase its density by heating, even at temperatures as high as 1,600 °C.

This work was done by David J. Green of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 120 on the TSP Request Card.*

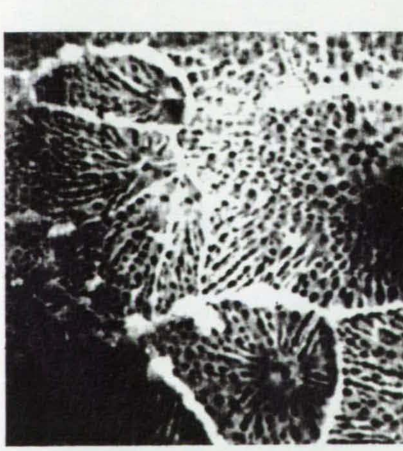
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Johnson Space Center [see page 14]. Refer to MSC-20782.



OPTICAL MICROGRAPH



SCANNING-ELECTRON MICROGRAPH



SCANNING-ELECTRON MICROGRAPH

Photographs of Increasing Magnification show loosely packed particles of the freeze-dried powders (top and middle). The porous surface of one particle is shown at the bottom.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Effects of Low Gravity on Superalloy Solidification

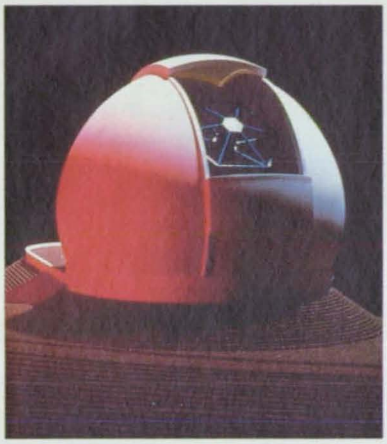
Interdendritic spacings and carbide contents increase.

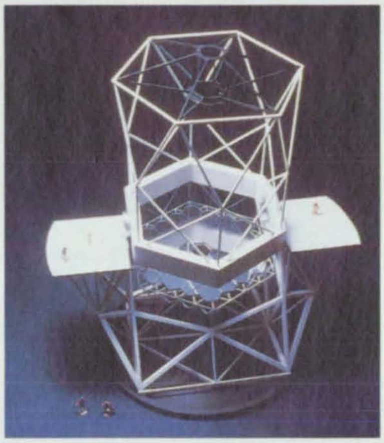
A report describes experiments on the directional solidification of MAR-M246(Hf) superalloy in low gravity. MAR-M246(Hf) is a nickel-based alloy containing 1.5 percent hafnium among other elements. The experiments were intended to determine the effects of the reduction in gravity (and consequently of convection in the melt) on the growth of dendrites and on the resultant interdendritic segregation of various constituents, particularly of the additive hafnium.

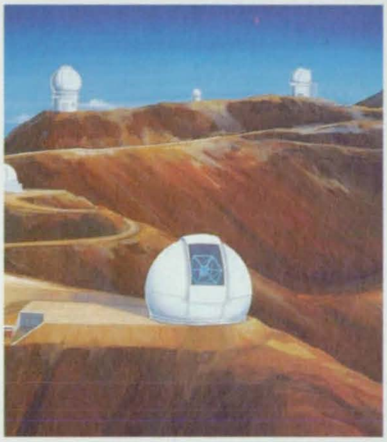
The microstructure of MAR-M246(Hf) includes a nickel-based matrix, carbides, and a γ/γ' eutectic. The precipitated γ' phase strengthens the nickel-based matrix. The hafnium is added because it serves as a carbide former and grain-boundary strengthener.

The alloy was directionally solidified in a furnace with a water-cooled quenching block in a KC-135 airplane. The samples were repeatedly subjected to about 10^{-2} normal gravity for about 30 s during flights on parabolic trajectories, followed by as much as 1½ min at about 1.8 times normal gravity during pullout and climb. Growth rates of 1.0 and 1.6 cm/min were selected because they produce excellent dendritic structures in the laboratory and enable about 5 mm of sample to be solidified during the low-gravity intervals. After solidification, the samples were polished and analyzed by standard micrographic and electron microprobe techniques. The spacings of secondary dendrite arms and the volume fractions of carbides were measured along the length of each sample.

The low-gravity portions of the samples show increases in the spacings of the primary and secondary dendrite arms and in the interdendritic segregation of hafnium. The latter effect is apparently due to the decrease of convection, which would normally serve to reduce the segregation. There is a consequent increase in the hafnium contents of the carbides. This causes the carbide particles to become more blocky, as usually happens when hafnium is added. The amounts of interdendritic constituents and carbides decrease with decreasing gravity; this is an effect usually seen when the interden-







dritic spaces increase as they do here.

Mechanical tests could not be performed because the samples were too small. However, the authors note that the microstructural changes produced by low gravity are traditionally associated with improvements in the mechanical properties of superalloys, including resistance to high-temperature fatigue.

This work was done by M. H. Johnston, R. A. Parr, P. A. Curreri, and Wendy Alter of **Marshall Space Flight Center**. *To obtain a copy of the report, "Gravity Level Induced Microstructural Variations in a Directionally Solidified Superalloy," Circle 30 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 14]. Refer to MFS-28027.

Solidifying Mn/Bi in a Magnetic Field

The magnetic effects are similar to those of low gravity.

A report describes experiments in the directional solidification of eutectic Mn/Bi in a magnetic field. The purpose of the study was to determine whether the effects of gravitationally-induced convection could be reduced or eliminated by the magnetic field. Morphological, thermal, and magnetic analyses were done on samples grown at various speeds and at various applied field strengths.

The microstructure of directionally solidified eutectic Mn/Bi is characterized by rods aligned with the direction of growth and interfaces between faceted and nonfaceted phases. In addition, the equilibrium phase of Mn/Bi exhibits strong ferromagnetism. Previous studies had indicated that when growth is carried out in low gravity to suppress convection, the Mn/Bi rod diameter, interrod spacing, and solidification temperature are reduced, whereas the magnetic properties are enhanced.

Samples of Mn/Bi 5 cm long were prepared in quartz crucibles. A subminiature thermocouple was placed 2 cm from the lower end of each sample to provide in situ temperature measurements. The samples were directionally solidified in a vertical, growth-up orientation in a Bridgman-Stockbarger furnace with a resistance-heated hot zone, a water-cooled chilling block, and an insulated adiabatic zone between. The samples were held stationary while the furnace was moved upward at speeds ranging from 0.2 to 50 cm/h. The thermal gradient in each sample was maintained at 100 °C/cm or 150 °C/cm. When the magnetic field was used, it was applied perpendicularly to the growth axis, usually at a strength of 3 kG.

At growth speeds below 0.5 cm/h, the magnetic field had no effect on the microstructure, which was characterized by nonaligned, irregularly dispersed Mn/Bi platelets. At growth speeds above 3 cm/h, the transverse magnetic field reduced the rod diameter and spacing, enhanced undercooling, and increased magnetic coercive strength. At a growth speed of 3 cm/h and in the magnetic field, the higher thermal gradient resulted in a more uniform Mn/Bi microstructure. These observations agree remarkably well with those obtained in low gravitation at 30 cm/h and 50 cm/h and are consistent with the theoretical prediction that the magnetic viscosity predominates over the buoyant forces that drive thermal convection under the given experimental conditions.

This work was done by J. L. DeCarlo and Ron G. Pirich of Grumman Aerospace Corp. for **Marshall Space Flight Center**. *To obtain a copy of the report, "Effect of Applied Magnetic Fields during Directional Solidification of Eutectic Bi-Mn," Circle 33 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 14]. Refer to MFS-28123.

Trifluorophenylethylidene Condensation Polyimides

Synthetic versatility provides high-T_g films and melt-fusible molding resins.

A report describes the synthesis and properties of trifluorophenylethylidene (3F) condensation polyimides. The properties of these new polymers may make them suitable as thermal-control coatings, interlayer dielectrics in advanced wafer chips, and electronic-multilevel-interconnection layers.

The hexafluoroisopropylidene (6F) connecting group used to prepare commercially available aromatic polyimides has been shown to result in resins with high glass-transition temperatures (T_g's) and excellent thermo-oxidative stability. Increases in the useful lifetime of 6F polyimides at temperatures up to 700 °F (371 °C) are desirable for use in jet engines. Increasing the T_g and the thermal/thermo-oxidative stability increases the potential for use at higher temperatures.

The 3F condensation polyimide resins are based on connecting linkages somewhat analogous to those in 6F polyimides. The 3F condensation polyimides represent the following: (a) an alternative to the 6F-based laminating resins presently commercially available, (b) a technology for new polyimide film products (6F resins are unavailable as films), and (c) an improvement over the existing 6F technology because of the "synthetic versatility" resulting from the use of the 3F phenyl ring as the site to modify polymer properties chemically. The latter capability is not available in existing 6F-resin technology because of the lack of the necessary phenyl ring as the synthetic site.

This investigation identified a synthetic route to the new 3F dianhydride monomer and improved the synthetic route to the existing 3F diamine monomer. These monomers were then used to synthesize nine new polyimides with 3F connecting linkages. Prepared by traditional condensation polymerization, these 3F polyimides had molecular weights higher than those of the analogously prepared 6F polyimides.

The 3F polymer solutions were thermally converted at 570 °F (299 °C) into polyimide films. These films were converted into molding powders and then into neat resin disks. The resin disks were prepared at temperatures up to 875 °F (468 °C). Isothermal-weight-loss studies identified two new polyimides containing 3F; namely, 3F-dianhydride/paraphenylene-diamine and 6F-dianhydride/3F-diamine. These polymers exhibited low weight losses similar to those of the oxidatively stable 6F-dianhydride/paraphenylene-diamine and pyromellitic-dianhydride/6F-diamine resins.

Test results indicated that the polyimides containing the 3F linkage exhibit T_g values and thermal/thermo-oxidative stabilities similarly high to those of polyimides containing the 6F linkage. Because of their expanded synthetic versatility, these 3F condensation resins represent the next generation of condensation polyimides.

This work was done by William B. Alston of **Lewis Research Center** *and Roy F. Gratz of Mary Washington College. Further information may be found in NASA TM-87113 [N86-12311/NSP], "Structure-to-Glass Transition Temperature Relationships in High Temperature Stable Condensation Polyimides."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center [see page 14]. Refer to LEW-14386.

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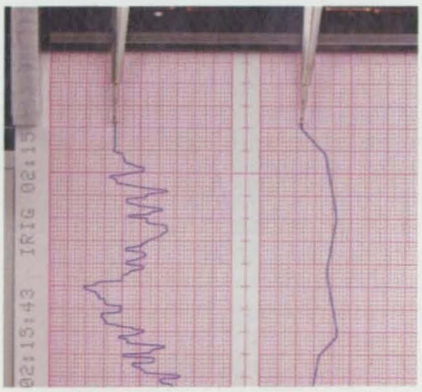

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Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to make raw programs available to the public. For information on program price, size, and availability, circle the reference number on the TSP and COSMIC Request Card in this issue.

Electronic Systems

A Computer System for Mission Managers

The system helps the mission manager coordinate diverse functions and produce documentation.

The Mission Managers' Workstation (MMW) is a personal-computer-based system providing data management and reporting functions to assist Space Shuttle mission managers. The full work station is composed of IBM PC hardware, packaged software, and custom software integrated into a friendly, menu-driven system. Before each Shuttle mission, a series of reports and flight-readiness documents must be issued and approved by the mission manager. MMW automates the production of these commit-to-flight documents. MMW also acts as a general productivity aid by providing central data storage and word processing.

There are four data bases incorporated in the package:

1. The Flights data base contains the bulk of information of planned Shuttle flights. It holds data applicable to launch, ascent, orbit, descent, cargo, structure weights, mission requirements and objectives, etc.
2. The Flight Experience data base stores combined information from previous flights.
3. The Mass Properties data base holds engineering specifications to aid in center-of-gravity modeling and calculations.
4. The Item Scheduler data base contains information about the series of events preceding launch day.

The work station allows the mission manager to relate events and stored data in a more timely and organized fashion. Using MMW, standard reports can be formatted, generated, edited, and electronically communicated with a minimum of clerical help.

MMW is written in PASCAL, BASIC, and assembler for interactive execution and has been implemented on an IBM XT computer operating under DOS with a central-memory requirement of approximately 640 K of 8-bit bytes and 10 Mbytes of hard-disk space. For full implementation, MMW also requires the following commercially available software: WordStar, SmartCom, Sidekick, R:Base 4000, Extended Batch Language, Fixed Disk Organizer, and File Path Program. This program was developed in 1985.

This program was written by Robert Tolchin, Sathy Achar, Tina Yang, and Tom Lee of Abacus Programming Corp. for **Johnson Space Center**. *For further information, Circle 71 on the TSP Request Card. MSC-21092*

Control-System Design Program

Multi-input and multioutput systems can be located in continuous and discrete forms.

This control-theory design package, called Optimal Regulator Algorithms for the Control of Linear Systems (ORACLS), was developed to aid in the design of controllers and optimal filters for systems that can be modeled by linear, time-invariant differential and difference equations. Optimal linear quadratic regulator theory, currently referred to as the Linear-Quadratic-Gaussian (LQG) problem, has become the most widely accepted method of determining optimal control policy. Within this theory, the infinite-duration, time-invariant problems, which lead to constant-gain feedback control laws and constant Kalman-Bucy filter gains for reconstruction of the system state, exhibit high tractability and potential ease of implementation.

A variety of new and efficient methods in the field of numerical linear algebra have been combined into the ORACLS program, which provides for the solution to time-invariant continuous or discrete LQG problems. The ORACLS package is particularly attractive to the control-system designer because it provides a rigorous tool for dealing with multi-input and multioutput dynamic systems in both continuous and discrete form.

The ORACLS programming system is a collection of subroutines that can be used to formulate, manipulate, and solve various LQG design problems. The ORACLS program is constructed in a manner that permits the user to maintain considerable flexibility at each operational state. This flexibility is accomplished by providing primary operations, analysis of linear time-invariant systems, and control synthesis based on LQG methodology.

The input/output routines handle the reading and writing of numerical matrices, printing heading information, and accumulating output information. The basic vector/matrix operations include addition, subtraction, multiplication, norm construction, tracing, transposition, scaling, juxtaposition, and construction of null and identity matrices. The analysis routines provide for the following computations: the eigenvalues and eigenvectors of real matrices, the relative stability of a given matrix, matrix factorization, the solution of linear constant-coefficient vector/matrix algebraic equations, the controllability properties of a linear time-invariant system, the steady-state covariance matrix of an open-loop stable system forced by white noise, and the transient responses of continuous linear time-invariant systems.

The control-law design routines of ORACLS implement some of the more common techniques of time-invariant LQG methodology. For the finite-duration optimal-linear-regulator problem with noise-free measurements, continuous dynamics, and integral performance index, a routine implements the negative-exponential method for finding both the transient and steady-state solutions to the matrix Riccati equation. For the discrete version of this problem, the method of backwards differencing is applied to find the solutions to the discrete Riccati equation. A routine is also included to solve the steady-state

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Riccati equation by the Newton algorithms described by Klein for continuous problems and by Hewer for discrete problems.

Another routine calculates the prefilter gain to eliminate control-state cross-product terms in the quadratic performance index and the weighting matrices for the sampled-data, optimal-linear-regulator problem. For cases with measurement noise, duality theory and optimal-regulator algorithms are used to calculate solutions to the continuous and discrete Kalman/Bucy filter problems. Finally, routines are included to implement the continuous and discrete forms of the explicit (model-in-the-system) and implicit (model-in-the-performance-index) model following theory. These routines generate linear control laws that cause the output of a dynamic time-invariant system to track the output of a prescribed model.

In order to apply ORACLS, the user must write an executive (driver) program that enters the problem coefficients, formulates and selects the routines to be used to solve the problem, and specifies the desired output. Three versions of ORACLS source code are available for implementation: CDC, IBM, and DEC. The CDC version has been implemented on a CDC 6000-series computer with a central-memory of approximately 13K (octal) of 60-bit words. The CDC version is written in FORTRAN IV and was developed in 1978. The IBM version has been implemented on an IBM 370-series computer with a central-memory requirement of approximately 300K of 8-bit bytes. The IBM version is written by FORTRAN IV and was generated in 1981. The DEC version has been implemented on a VAX-series computer operating under VMS. The VAX version is written in FORTRAN 77 and was generated in 1986.

This program was written by Harold P. Frisch of **Goddard Space Flight Center**. *For further information, Circle 83 on the TSP Request Card.*
GSC-13067

Mathematics and Information Sciences

Program Generates Views of Complicated Objects

Line drawings and other representations are produced by computer-aided design.

PLAID is a three-dimensional Computer Aided Engineering (CAE) program that enables the user to construct, manipulate, and display interactively highly complex geometric models. PLAID was initially developed by NASA to assist in the design of Space Shuttle crew-station panels and in the assessment of payload handling. It has evolved into a more general program for convenient use in many engineering applications. Special effort was made to incorporate techniques and features that minimize the user's workload in designing and managing PLAID models.

PLAID consists of three major modules: the Primitive Object Generator (BUILD), the Composite Object Generator (COG), and the DISPLAY Processor. The BUILD module provides a means of constructing simple geometric objects called primitives. The primitives are created from polygons that are defined either explicitly by vertex coordinates or graphically by the use of terminal crosshairs or a digitizer. Solid objects are constructed by combining, rotating, or translating the polygons. Corner rounding, hole punching, milling, and contouring are special features available in BUILD.

The COG module hierarchically organizes and manipulates primitives and other previously defined COG objects to form complex assemblies. The composite object is constructed by applying transformations to simpler objects. The transformations include scalings, rotations, and translations. These transformations may be defined explicitly or defined graphically using the interactive COG commands.

The DISPLAY module enables the user to view COG assemblies from arbitrary viewpoints (inside or outside the objects) both in wire-frame and hidden-line renderings. The PLAID projection of a three-dimensional object can be either orthographic or with perspective. A conflict-analysis option enables the detection of spatial conflicts or collisions. DISPLAY provides camera functions to simulate a view of the model through different lenses. Other features include the generation of hard-copy plots, scaling and zoom options, distance tabulations, and descriptive text in different sizes and fonts.

An object in the PLAID data base is not just a collection of lines; rather, it is a true three-dimensional representation from which correct hidden-line renditions can be computed for any specified eye point. The drawings produced in the various modules of PLAID can be stored in files for future use.

PLAID is written in FORTRAN 77 for single-user interactive execution and has been implemented on a DEC VAX-series computer operating under VMS with a recommended core memory of four M-bytes. PLAID requires a Tektronix-4014-compatible graphics display terminal and optionally uses a Tektronix-4631-compatible graphics hard copier. Plots of resulting PLAID displays may be produced using the Calcomp 960, HP 7221, or HP 7580 plotter. Digitizer tablets can also be supported.

This program was written by Jeri W. Brown of **Johnson Space Center**. *For further information, Circle 39 on the TSP Request Card.*
MSC-21172

Managing Development and Maintenance of Software

This computer program assists in the development of other computer programs.

The Source Management Utility (SMU) computer program is a tool to manage the development and maintenance of computer software. Its purpose is to control an organization of configured data sets that contain source, object, and load-module files.

At each step of the development process, SMU produces files that trace the revision history of a particular program. Programs can be controlled by restricting compilation or linking privileges and by requiring a designated primary user to authorize all changes. SMU provides an easy-to-use method of software management by supplying source-code control, tracing of all software modifications, and historical documentation.

SMU builds a data base of configured files with particular formats, file specifications, etc. Common file types include FORTRAN, PL/1, PASCAL, ASM, JCL, CLIST, and TEXT. The SMU system contains a user-interface program based on the IBM ISPF facility program for screen formatting and user dialog. The user can interactively perform such software-maintenance functions as create, edit, compile, link, and load (subject to approval by the primary user).

SMU manages file-history data sets that can be viewed by the user for dates, code changes, reasons, etc. Using SMU commands, local files can be compared to the "official" production version, the availability of data sets can be confirmed, and previous program versions can be fully restored.

SMU is written in PL/1 and assembler for interactive execution and has been implemented on an IBM 3030-series computer operating under OS/MVS with a central-memory requirement of approximately 200K of 8-bit bytes. SMU requires the IBM programs TSO and ISPF. Installation of the SMU system requires knowledge of the AS/MVS operating system. Release 3 of SMU was developed in 1985.

This program was written by Gerald W. Rook and David E. Statezni of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 160 on the TSP Request Card.*
MSC-21142

Only one video camera can be any video camera you want it to be.

Available on GSA Contract GSOOK87AGS0101.

Imagine being able to design a camera to suit your every need. You can with the Panasonic® WV-D5000 because it's totally modular. Just choose the ENG, EFP, or studio configuration that's right for you.

The WV-D5000 is even more versatile. You can use some of the world's finest photographic lenses. Lenses you may already own. Lenses from Canon, Pentax, Minolta, Olympus and Nikon. Wide angle lenses. Long lenses. Lenses for telescopy and microscopy.

And if that isn't impressive enough, the WV-D5000 has a strobe-effect shutter speed of 1/1000th of a second. That means you can shoot high-speed action like a roller coaster and during VCR playback actually see the excitement on a child's face.

But whether the action is fast or slow, the WV-D5000's CCD pickup element provides clear, stable video images with a minimum of blooming and burn-in. Horizontal resolution is a hefty 380 lines while S/N is a quiet 46dB. And when it comes to light, you need only 0.7 footcandles at f1.4.

You'd expect a camera of this caliber to be fully flexible, and the WV-D5000 fulfills your every expectation. With auto-tracing white balance, intermittent recording as well as audio and video fade-in and fade-out.

The Panasonic WV-D5000. It's the one video camera you can customize to be any video camera.

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Professional/Industrial Video

For more information and your copy of the Authorized Communications Schedule Price List contact your local Panasonic Industrial Video dealer or call (703) 486-5533 (FTS: (202) 486-5533) or write to Government Marketing Dept., Panasonic AVSG, Suite 901, 1215 Jefferson Davis Highway, Arlington, VA 22202-4302.

Circle Reader Action No. 380

Mechanics

Hardware, Techniques, and Processes

Sealed Joints for Hard Suits or Robots

Developed for space suits, the joint principle has other applications.

Ames Research Center, Moffett Field, California

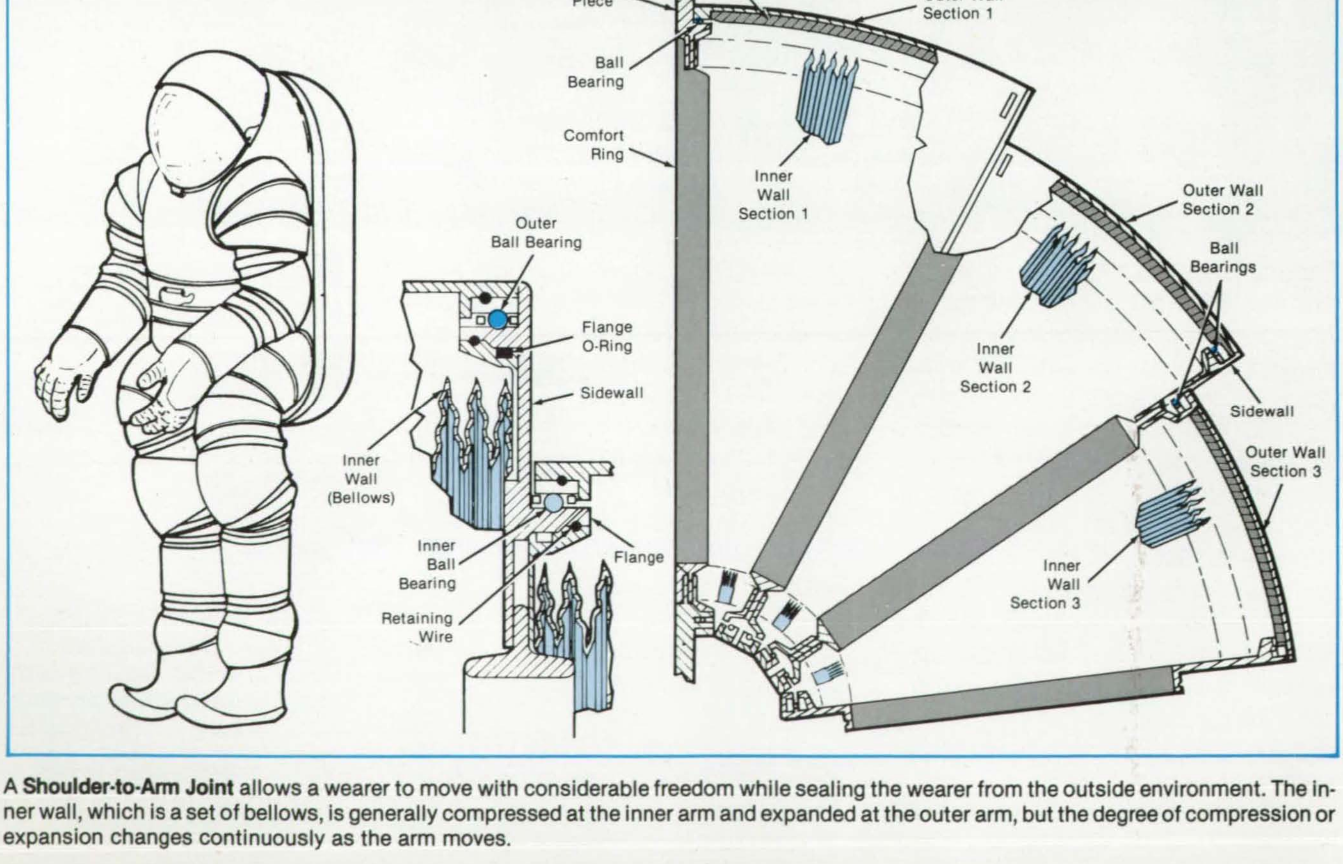
A double-walled joint allows relative movement, including rotational movement, between members while sealing the interior from the external environment. Developed for shoulder-to-arm and hip-to-leg connections in space suits, the joint may also be used on diving suits and on manipulation sleeves for autoclaves and high-vacuum boxes. It can be used as a protective cover for articulated torque drives in hostile environments.

The outer wall of the joint is made of a hard material, such as rigid plastic or metal, in the form of toroidal sections. The outer sections rotate on ball bearings in cylindrical flanges on their ends. The inner wall is a bellowslike sleeve. Each section of the outer wall can turn independently of the other sections, clockwise or counterclockwise, through angles up to 360°.

The inner wall does not rotate with the outer sections but expands and contracts locally to accommodate their rotation. The inner wall thus maintains a seal, while the outer wall protects against mechanical damage. Together, they allow the wearer to move with minimal hindrance.

In a shoulder/arm joint, for example, three sections of progressively smaller size are used (see figure). The ends of the sections are circular and lie on intersecting planes. Each section has two ball-bearing races. Because the sections have differing diameters, a sidewall extends from the edge of a larger section to the ball-bearing race that joins it to an adjacent smaller section. Thus, each sidewall has an eccentric circular aperture that is concentric with an inner ball-bearing race. A flange at the outer diameter of the sidewall forms the race of the larger ball bearing of the larger section. Another flange at the smaller eccentric hole on the sidewall forms the smaller ball-bearing race, that joins the larger section to the smaller section.

An inner bellows wall is positioned within each outer wall section. A bellows is connected to its respective outer sec-



A **Shoulder-to-Arm Joint** allows a wearer to move with considerable freedom while sealing the wearer from the outside environment. The inner wall, which is a set of bellows, is generally compressed at the inner arm and expanded at the outer arm, but the degree of compression or expansion changes continuously as the arm moves.

tion by welding, brazing, or adhesive bonding it to attachment flanges. This connection and O-rings hermetically seal the interior of the joint. The space between a bellows and its outer wall may contain thermal insulation or radiation shielding.

Comfort rings protect the wearer from chafing against the flanges of the outer wall sections. They are made of a rubberlike material.

The topmost outer wall section is coupled to the shoulder piece by a ball bearing. Thus, this wall section can rotate with respect to the shoulder piece. Its bellows section, however, does not rotate with respect to the shoulder piece; an O-ring and a retaining wire prevent relative motion between the bellows-attachment flange and the interior ball-bearing race of the joint. Similarly, the succeeding sections of outer wall are free to rotate with respect to each other. Their bellows, however, are restrained by O-rings and retaining wires. Each bellows remains stationary with respect to the shoulder piece. Instead of rotating, the bellows undergo local compression and expansion changes as the wearer moves the arm. The sections can be removed and added for replacement or to shorten or lengthen the joint. When the retaining wires are in place, the sections are held securely together. When a retaining wire is withdrawn, however, the adjacent section can be removed. When a new section is added, the wire is reinserted and holds the new section in place.

This work was done by Hubert C. Vykukal of **Ames Research Center.** *For further information, Circle 57 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11534.

Coatings Show Laminar Boundary-Layer Transitions

Color changes in liquid crystals reveal changes in shear stress.

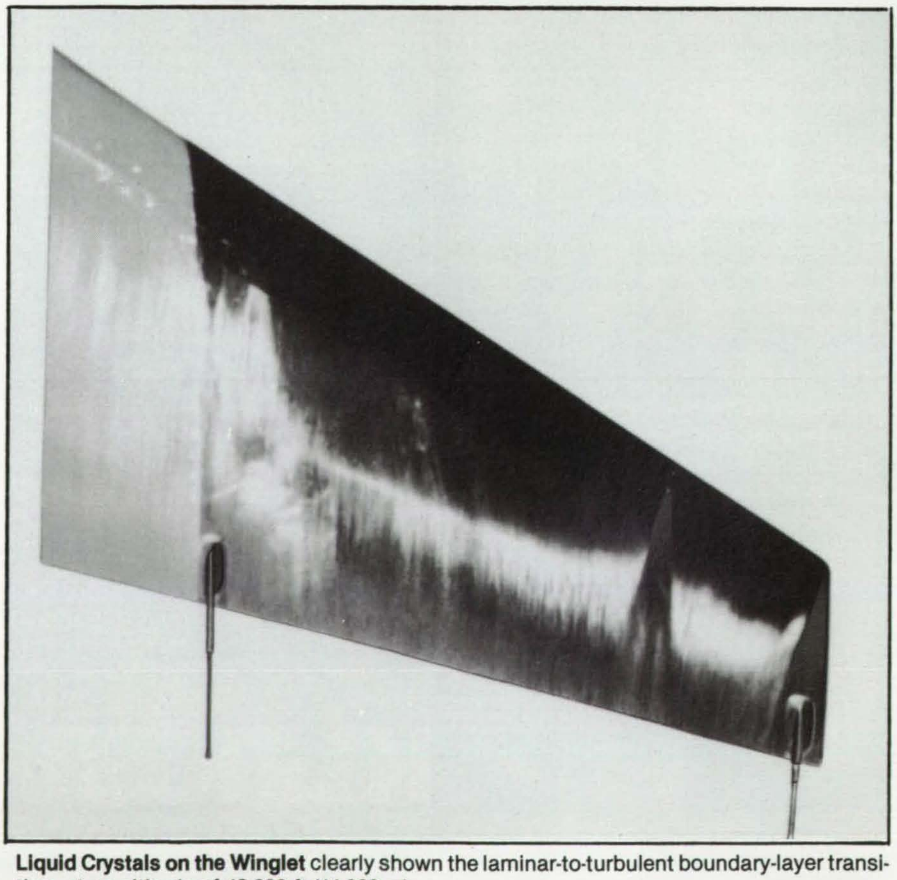
Langley Research Center, Hampton, Virginia

The visualization of the laminar-to-turbulent boundary-layer transition plays an important role in flight and in wind-tunnel aerodynamic testing of aircraft wing and body surfaces. A new method, utilizing liquid-crystal coatings, provides a means to visualize this transition in flight. The difference in levels of relative shear stress or skin friction between laminar and turbulent boundary layers is about one order of magnitude; turbulent skin friction can be about 10 times as great as laminar skin friction. This difference in skin friction is the physical parameter to which the liquid crystals respond. The transition can be measured and documented on aircraft in flight at altitudes above 20,000 ft (6,100 m), up to at least 50,000 ft (15,000 m) at subsonic and supersonic speeds. The technique has rapid response and is reversible; it has the capability of indicating an unlimited number of transition locations during a single flight.

Liquid crystals belong to a peculiar state of matter between solid and liquid in which molecules are elongated in one direction. Although they appear as oily liquids, they have certain properties of solid crystals. In particular, they scatter light very selectively. Because of their peculiar molecular structure, liquid crystals change colors in response to changes in shear stress, temperature, ferromagnetism, and chemical vapors. Since its chemical structure is unaffected by these changes, a liquid-crystal coating will respond repeatedly to the same physical changes.

Available liquid crystals include those that operate at virtually all altitudes and speeds of interest in flight applications and which can be formulated to change colors across the entire visible spectrum, from red to violet, over a temperature range as small as 1.8 °F (1 °C) or as large as 90 °F (50 °C). For flight applications, it is usually desirable to use formulations with as wide a temperature band as possible to allow for transition measurements over a large range of altitudes in one flight. With care, the liquid crystals can be used to indicate the locations of such other aerodynamic phenomena as shock locations and laminar-separation bubbles. Since the response time of a liquid crystal coating can be less than 0.2 second, real-time observations of transition motions with changing flight conditions are possible.

Various application techniques are effective. The best visual and photographic results have been obtained by using the liquid-crystal coatings applied over flat black surfaces, although good transition patterns have been observed on other dark-colored backgrounds as well. The liquid crystal material can be applied by hand rubbing, with a brush, or by spraying. It is important that the coating have uniform thickness for maximum clarity in transition-



Liquid Crystals on the Winglet clearly shown the laminar-to-turbulent boundary-layer transition, at an altitude of 48,000 ft (14,600 m).

pattern development. Coatings that are too thick will run under aerodynamic loading, and thicker coatings can affect the transition location. Although a single coating can be used repeatedly, liquid crystals are sensitive to ultraviolet light and can eventually cease to operate.

The figure shows transition on a Lear-jet winglet in flight using a chiral nematic liquid crystal coating on a flat black background. This particular formulation had a temperature-response range beginning at −22 °F (−30 °C), and the flight conditions were an altitude of 48,000 ft (14,600 m) at mach 0.8. Percent chord location markings appear at the lower edge of the black region, and the transition is indicated clearly by a color change near the 60-percent chord location. The wedge-shaped turbulent region near the winglet tip was caused by an intentional roughness trip.

Excellent correlations have been observed between the transition indicated by liquid crystals and the transition indicated by other methods, including sublimating chemicals, oil flow, and hot films. Liquid crystal coatings are also useful for wind-tunnel and water-tunnel testing and can provide indications of shock-wave locations.

Results can be recorded on still or motion photographic film or on video tape. The best results were obtained with lighting emanating from behind the viewer and camera and onto the coated surface. The use of a polarizing filter on the camera lens provides improved color rendition under many lighting conditions. Even with less-than-optimum lighting angles for the camera, transition locations are still readily discernible by the human eye.

This work was done by Bruce J. Holmes, Peter D. Gall, Cynthia C. Croom, Gregory S. Manuel, and Warren C. Kelliher of **Langley Research Center**. *Further information may be found in NASA TM-87666 [N86-21518/NSP], "A New Method for Boundary Layer Transition Visualization In Flight — Color Changes in Liquid Crystal Coatings."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 14]. Refer to LAR-13554

Thermally Activated Driver

A precise, large-force driver has many potential applications and requires no power.

Langley Research Center, Hampton, Virginia

A space-qualified, precise, large-force, thermally activated driver (TAD) has been developed for use in space on an astrophysics experiment to measure the abundance of the rare actinide-group elements in cosmic rays. These actinide abundances, which hold clues to the origin and evolution of cosmic rays, will be determined through analyses of energetic-particle tracks in stacks of thin plastic sheets after the sheets have been exposed in space for a number of years and then recovered. Etching of the plastic sheets after they are penetrated by elements results in conical pits at each track site. With proper analysis of the etch pits, the abundances of the actinide elements can be established.

One requirement in this technique is that the temperature of the plastic stacks at the time a track is produced, a critical item of information in the analysis of etch pits, must be known to within 1 °C. The precise TAD was developed to be the heart of the event thermometer (ET) system that will be used on the mission. The ET system is illustrated in Figure 1. Two plastic sheets

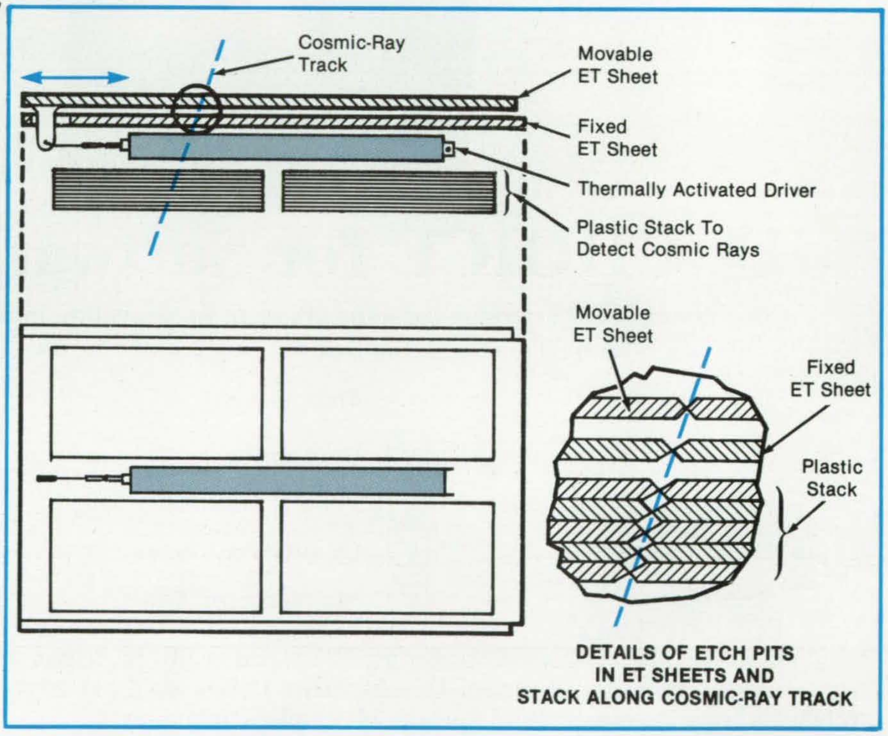


Figure 1. **Actinide Cosmic Rays** will be detected using the thermally activated driver as the heart of the event-thermometer (ET) system.

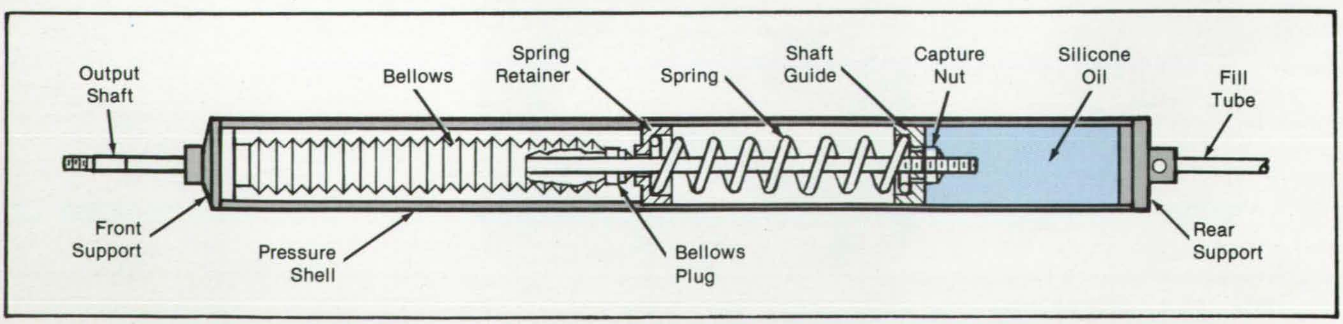


Figure 2. **Thermal Expansion and Contraction** of the silicone oil activates the driver.

are mounted above the detector stacks. The upper sheet is movable, and its position relative to the lower sheet is controlled, as a function of the temperature of the detector stacks, by the TAD. During post-flight analysis of the etched plastics, the temperature of the stack at the time a given track was produced will be determined by aligning the track etch pit in the movable sheet with that in the fixed sheet, noting the stack temperature required for the driver to so position the sheets.

The operation of the TAD, shown in Figure 2, is the result of the expansion or contraction of an incompressible fluid as the temperature of the fluid changes. A coil spring controls the position of the output shaft by applying a resisting force to the pressure force on the piston. Since the output shaft is welded to the bellows plug, the output shaft tracks the movement of the bellows and fluid.

Forty-five TAD's will be flown on the astrophysics actinide experiment. It is expected that TAD's will also find use in a number of other space and terrestrial applications. TAD's have potential applications in fluid-control systems where precise valve controls are needed. TAD's may be used to drive thermal-control louvers for spacecraft or for terrestrial buildings, or to compensate for thermal expansion and distortion of spacecraft structures where extreme dimensional stability is essential. With properly selected fluids, fluid volumes, and bellows sizes, TAD's can offer a wide choice in such performance variables as displacements, operating temperatures, driving forces, and response times.

This work was done by William H. Kinard of **Langley Research Center** *and Robert C. Murray and Robert F. Walsh of PRC Kentron, Inc. For further information, Circle 27 on the TSP Request Card.*
LAR-13583

High-Lift, Low-Pitching-Moment Airfoils

Two families of airfoil shapes improve rotor performance.

Langley Research Center, Hampton, Virginia

In wind-tunnel tests, two families of airfoil shapes perform better than prior airfoil sections. These improvements were sought to enhance the performances of helicopters and other rotorcraft but are also applicable to aircraft propellers. The airfoil shapes are best suited for an inboard segment of a rotor blade.

Rotor-blade aircraft put special demands on rotor airfoils because of the combined rotational and linear motion. For instance, on a single revolution of a rotor, an airfoil section can experience lift coefficients from negative values to the maximum positive value and section mach numbers from subsonic to transonic values. The airfoil profiles shown in Figure 1 are two members of the airfoil families that have the desired characteristics of an inboard section of a rotor-blade airfoil. Even the small difference in shape shown here results in significant differences in performance, and both families of airfoils have demonstrated substantial improvement in performance over prior airfoil shapes.

An airfoil of either family is one that could be produced by the combination of the camber line shown in the lower part of Figure 2 and a thickness distribution shown in the upper part of Figure 2, or one scaled from those shown. An airfoil of either family has a particular upper and lower surface shape that results in a unique and improved aerodynamic performance. The specific shapes of the airfoil profiles in both families simultaneously permit high maximum lift coefficients at mach numbers up to 0.50, low pitching-moment coefficients about the quarter chord for lift coefficients from −0.2 to 1.0 at mach numbers up to 0.63, and high drag-divergence mach numbers at lift coefficients from 0.0 to 0.30.

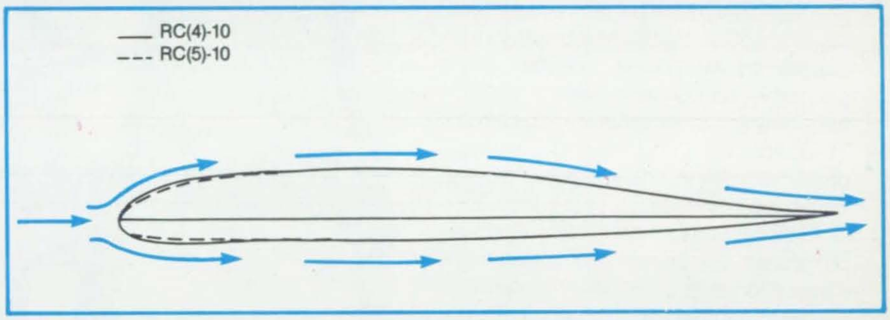


Figure 1. These **Airfoil Profiles** represent two members of the improved airfoil families.

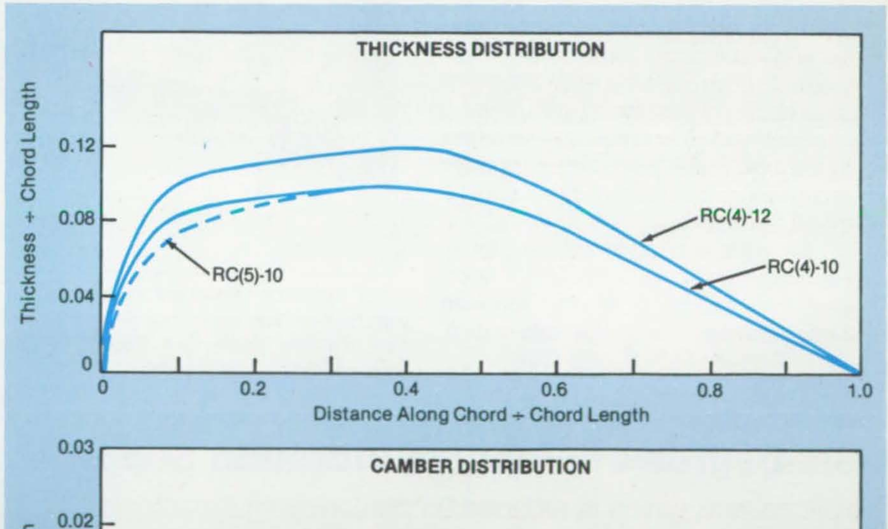


Figure 2. **Three Representative Airfoils** of the two airfoil families have these thickness and camber distributions. The camber distribution is common to all members of both families.

This work was done by Kevin W. Noonan of Aerostructures Directorate, U.S. Army Aviation Research and Technology Activity — AVSCOM, located at **Langley Research Center**. *For further information, Circle 50 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 14]. Refer to LAR-13215.

Electronic Caliper Has 1-mil Accuracy

Its output is either a digital readout or a printout.

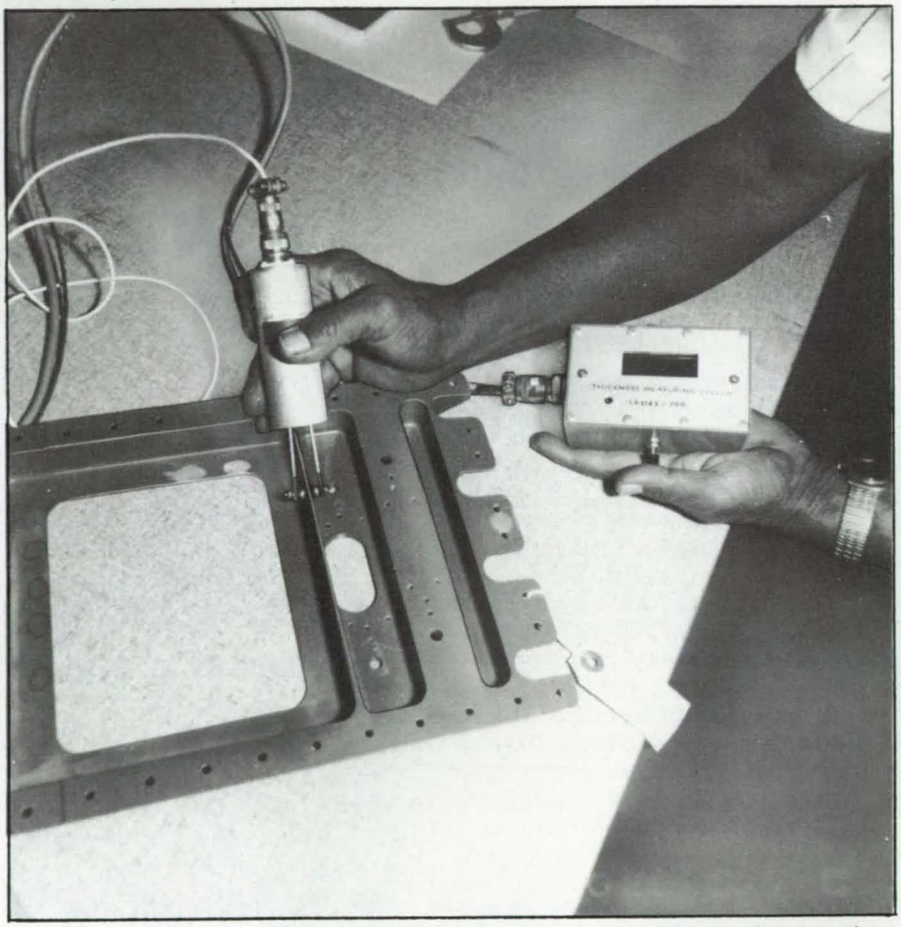
Lyndon B. Johnson Space Center, Houston, Texas

A new electronic caliper is accurate within ±0.001 in. (0.025 mm) and provides both a printout and a digital display of thickness. Measurements take less than one-tenth the time of mechanical-micrometer measurements.

The new instrument employs a tweezerlike probe with a ball on the tip of either finger (see figure). The balls and fingers are displaced by the part to be measured, causing a strain that is measured by strain gauges on the fingers. The four strain gauges — on opposite sides of both fingers — are connected in a bridge circuit. The output voltage of the bridge varies in proportion to the change in the gap between the fingertips.

A digital display and calibration unit processes the signal and displays the measured value in inches. The operator can also use a smaller display unit, driven by the main unit. By keeping the small display close to the probe, the operator can quickly discern out-of-tolerance thicknesses and undercuts in corner radii. The operator can then use a trigger switch on the small display to command a printout of the measurements. The printer — also driven by the main unit — prints the part number and measurement locations as well as the measured values.

This work was done by Douglas B. Harrington and Lino A. Aragon of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 2 on the TSP Request Card.*
MSC-20388



The **Operator Slides the Probe** along a rib while measuring the thickness between the probe tips. The measured value appears on the small display in the operator's hand as well as on a main display unit. The operator can order a printout of measurements by pushing the switch near his left thumb.

Six-Degree-of-Freedom Vibration Suppressor

Helicopter vibration is reduced 95 percent from the rotor hub to the pilot's seat.

Langley Research Center, Hampton, Virginia

The development of methods for reducing helicopter vibrations has been an important subject of research because vibrations have an adverse effect on helicopter airframe fatigue life, electronic-equipment failure rates, and crew and passenger comfort. In some cases, vibrations can limit the forward speed of the aircraft. A promising new system, the total-rotor-isolation system (TRIS) that employs liquid-inertia vibration-eliminator (LIVE) units, has been designed to isolate all six degrees of freedom of aircraft-fuselage dynamic response from the continuously changing airloads developed by the rotor.

Each LIVE unit is a two-cylinder, two-reservoir, tuned-port arrangement that uses liquid mercury as a hydraulic fluid. The figure shows a LIVE unit schematically in cross section. An inner cylinder is bonded to an outer cylinder with a layer of rubber, as in a coaxial-bushing rubber spring. Top and bottom cavities are enclosed, creating reservoirs for the mercury. The inner cylinder is attached to the fuselage. The hole, or tuning port, through the inner cylinder connects the upper and lower reservoirs.

A verification study was conducted in flight to demonstrate 90-percent (or greater) isolation of the helicopter fuselage from force and moment inputs at the rotor hub, at the blade-passage frequency, for the TRIS-configured Bell 206LM helicopter used as the test bed. By using six pinned/pinned isolator links attaching the

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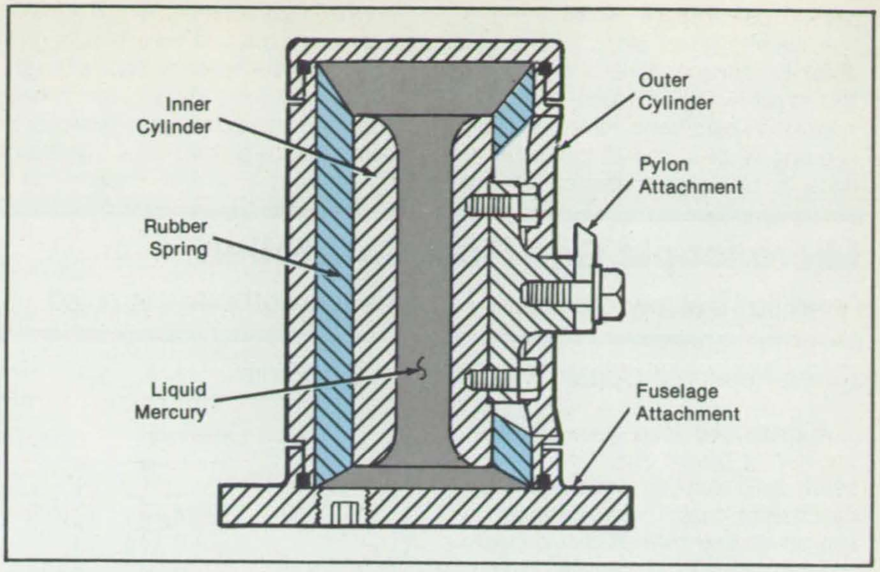
pylon to the fuselage (This can be done in any configuration that is statically stable in all six degrees of freedom), every attachment isolated the blade-passage frequency, and no oscillatory loads were transmitted in any degree of freedom.

The TRIS proved very effective in reducing vibration levels. The results of flight tests generally indicated at least a 95-percent reduction in vibration levels from the rotor hub to the pilot's seat. Also, the helicopter could be flown at maximum continuous power with no discomfort, at a speed approximately 15 mi/h (6.7 m/s) faster than the speed at which a pilot normally cruises the unmodified helicopter.

This work was done by Dennis R. Halwes of Bell Helicopter Textron, Inc. for **Langley Research Center**. *For further information, Circle 63 on the TSP Request Card. LAR-13581*



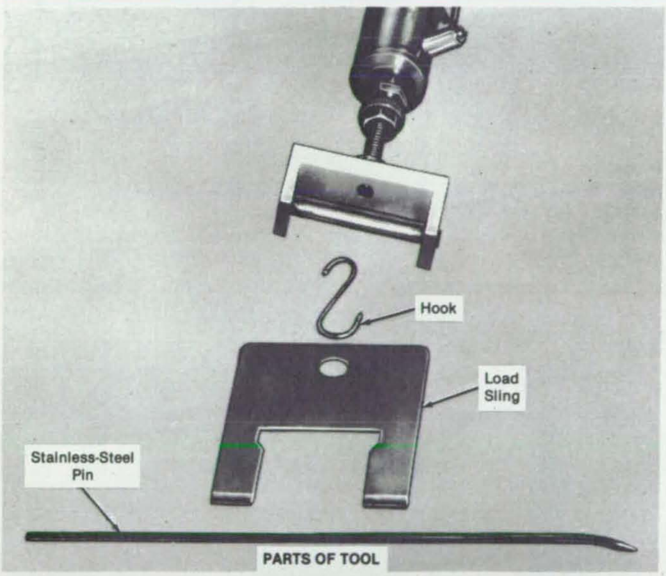
The **Vibration Suppressor** uses liquid mercury to damp vibrations.

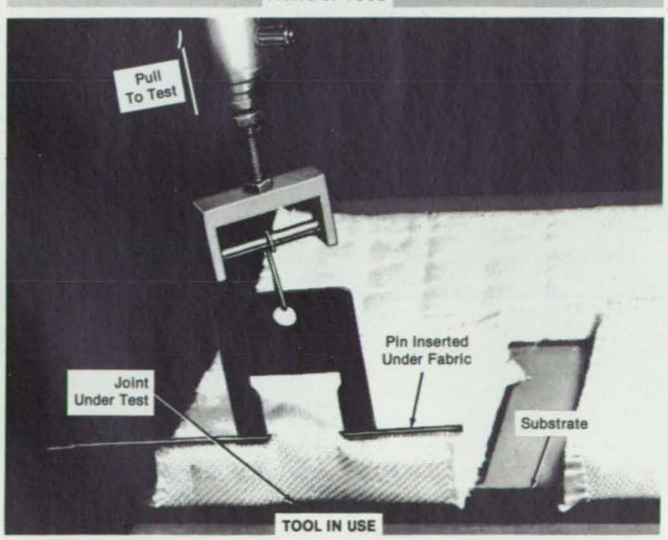
Testing Adhesive Bonds to Cloths

A nondestructive tool is simple and inexpensive.

Lyndon B. Johnson Space Center, Houston, Texas

An easy-to-use tool nondestructively tests the strength of an adhesive bond between a cloth and a straight rigid edge. The tool was developed for testing the advanced flexible reusable surface insulation





A **"Fish-Scale" Tension Meter** pulls on an insulation blanket to test the blanket-to-substrate bond.

blankets on the Space Shuttle.

A stainless-steel pin is inserted just under the surface fabric of a blanket so that its pointed tip protrudes, as though a large stitch were being made (see figure). The fingers of a load sling are hooked under the pin where it enters and emerges from the fabric. The load sling is hooked on a tension scale, and the user pulls on the scale until the specified bond strength is reached. The blanket and the adhesive bond will be undamaged, provided that both meet the specifications. The test can be repeated at several locations on the blanket.

This work was done by David G. Thomann of Rockwell International Corp. for **Johnson Space Center**. *No further documentation is available.*
MSC-20707

Microscopic Gas-Flow Controller

Small flows at low pressures would be monitored and throttled.

Ames Research Center, Moffett Field, California

A proposed flow-controlling and -measuring device would be made by batch solid-state microelectronic-fabrication techniques. The device would contain an ultrasensitive silicon capacitive pressure transducer, gas-flow channels etched in a silicon wafer, and integrated microvalves. The device is to be used to control and monitor low gas flows at low pressures; for example, in reactive-ion etching equipment or chemical-vapor deposition equipment in the semiconductor industry.

The flow-control and -measuring concept is illustrated by an electrical analog in Figure 1. Gas flows from a pressurized source through a parallel set of narrow channels, each of which provides a known resistance to the flow. The main flow is through channel 1, characterized by flow resistance R_1.

Additional small flow increments are obtained by opening the valves in one or more of the parallel flow channels. This enables fine adjustments of the total flow. The flow resistances in the n parallel channels are in multiple powers of 2 times the flow resistance of channel 2 so that the flow increments can be chosen in small uniform steps over a range of $2^n - 1$ times the smallest step.

The flow is measured in terms of the pressure drop along channel 3, represented in Figure 2 by the flow resistance R_3. R_3 should not exceed R_1 so that the incremental flows through the parallel channels will provide an adequate range of adjustment of the overall flow.

The device consists of the working parts in an integrated silicon wafer sandwiched between two pieces of glass or two other silicon wafers. The silicon could be attached to the glass by electrostatic bonding. The channels would be made by applying anisotropic etchants to the silicon surface. Such etchants can be controlled to produce channels of the precise dimensions needed for the desired flow resistances.

One of the electrodes of the capacitive pressure sensor is a thin layer of metal on the glass plate. The other electrode is a thin, boron-doped silicon diaphragm that deflects in response to the pressure difference along R_3. The deflection causes a change in capacitance, which is measured by an external circuit.

Each valve includes a slightly raised

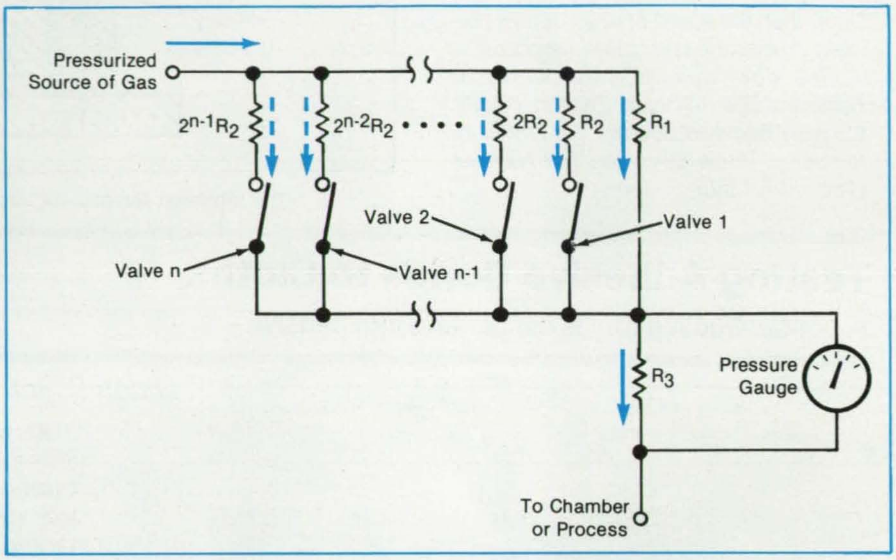


Figure 1. **Gas Flows Through Narrow Passages** of known flow resistance. Different flow resistances are switched in or out to alter the flow. The flow configuration is depicted in the manner of an electrical circuit because the gas flow and pressure are analogous to electrical current and voltage, respectively. The opening of a valve is represented by the closing of a switch and vice versa.

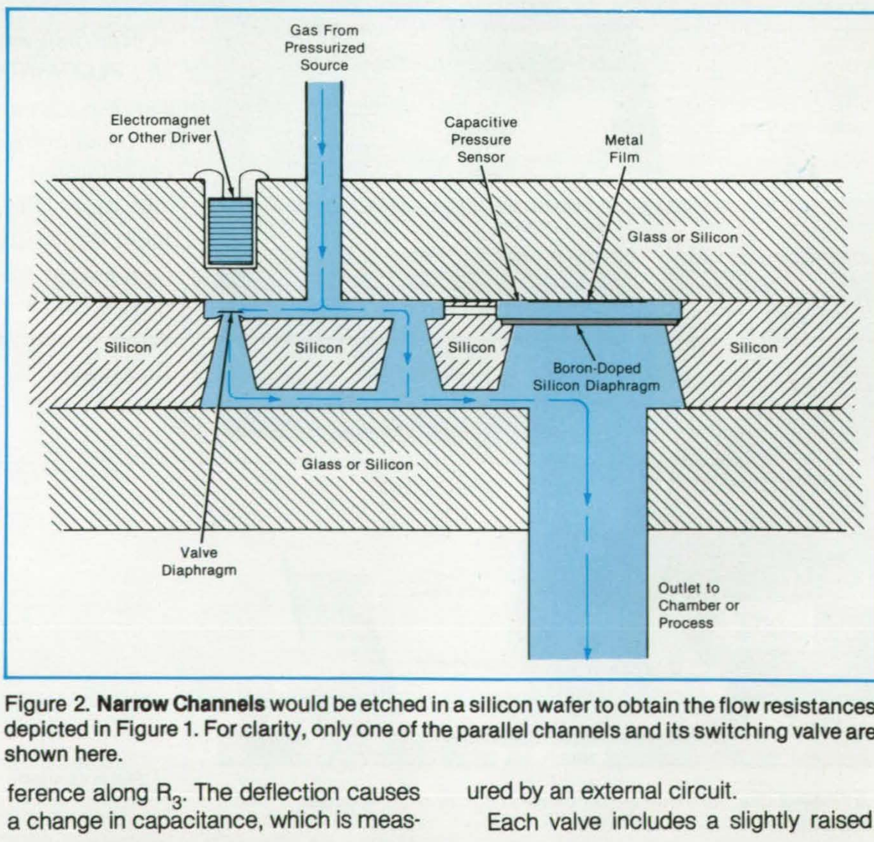


Figure 2. **Narrow Channels** would be etched in a silicon wafer to obtain the flow resistances depicted in Figure 1. For clarity, only one of the parallel channels and its switching valve are shown here.

valve seat covered by a thin undercut diaphragm of polysilicon or other material. The valve diaphragm and seat are formed in a monolithic batch process as part of the wafer-fabrication sequence. The diaphragm can be coated with nickel or another magnetic material to allow magnetic drive as shown, lifting the diaphragm away from the valve seat. Alternatively, electrostatic drive could be used. The process is compatible with the integration of circuitry on the structure for flow sensing and control.

This work was done by Kensall D. Wise of the University of Michigan for **Ames Research Center**. *For further information, Circle 44 on the TSP Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11704.

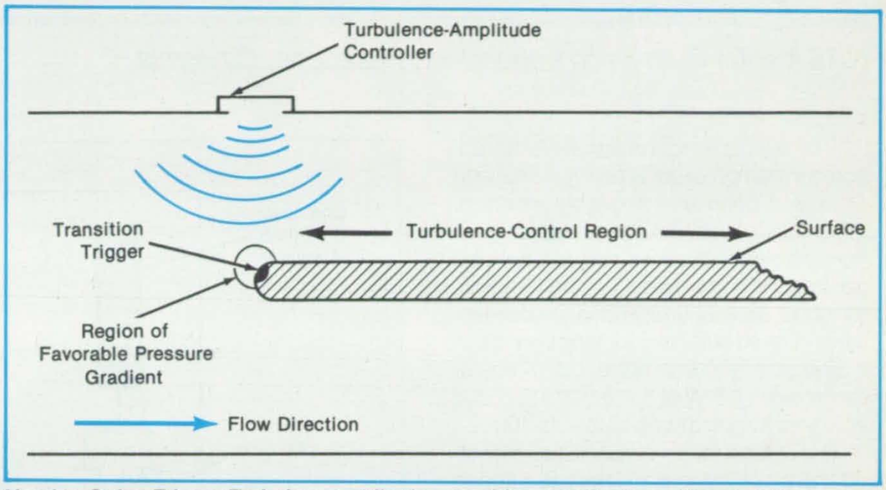
Active Control of Transition and Turbulence

Lower skin-friction drag is achieved downstream of a turbulance trigger.

Langley Research Center, Hampton, Virginia

Two active means of manipulating boundary-layer flow have been developed, one controlling the laminar-to-turbulent transition, the other controlling the amplitude of the turbulent fluctuation. The purpose is to control skin-friction drag over surfaces inside inlets and ducts. The resulting turbulence downstream has lower skin-friction drag than does the equivalent flow that develops over the same surfaces in the absence of intervention.

The control mechanism consists of a transition trigger and a turbulence controller, as shown in the figure, actively operated via a feedback mechanism with an amplitude and time-response level suitable for triggering broad ranges of levels and bandwidths. The transition trigger is a heating strip or strips embedded in a thermally neutral substrate mounted flush with the surface. The controller is an acoustic source placed above or within the surface.



Heating Strips Trigger Turbulence while the transition amplitude and bandwidth are controlled by an acoustic signal.

This technique is used in the region of favorable pressure gradient induced by a convex curvature or by artificial means. In this region, the flow stretches and becomes mostly receptive to such outside influences as surface heat or sound. Thus one can easily trigger small- or large-amplitude disturbances as well as impart instant transition. This coupling is utilized in a wind-tunnel experiment to trigger instant transition. In addition, feedback control by sound interaction with the transitional flow produces a significant reduction in amplitude. The results from the experiment indicate that this is an effective way to control the amplitude of the fluctuations at transition and beyond. From this process, the resulting flow has lower-amplitude perturbations and lower skin-friction drag.

This work was done by Lucio Maestrello of **Langley Research Center**. *For further information, Circle 48 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 14]. Refer to LAR-13532.

New Products

To learn how composite technology can help you design unique characteristics into your components, request the new brochure from **Tech Composites** (Tempe, AZ), manufacturers of custom designed precision composite components for aerospace, automotive and general industrial applications. Featuring thermoplastic injection molded technology, the guide highlights all aspects of the injection molding process from design engineering and tooling to volume production and value added services. To help select composite resins, the guide compares 17 resin formulations. **Circle Reader Action Number 590.**

Providing a temperature range of -100°F to 375°F, **Cincinnati Sub-Zero**'s (Cincinnati, OH) Model BZ-1.6 benchtop test chamber includes a microprocessor single setpoint temperature control and works on a standard 115 volt, 20 ampere power circuit. Cooling compressors provide 400 watt heat load holding capacity at -90°F. The test chamber's optional microprocessor profiling controller has 51 ramp/soak segments, eight on/off event relays, and a failsafe high/low digital temperature limit/alarm. The liner is 304 brushed stainless and hermetically sealed, while the exterior finish is a durable oven baked powder coating. Other standard features include cable access port, refrigeration service taps, and a five year limited compressor warranty. **Circle Reader Action Number 591.**

Originally designed as a flight control for a surface-to-air missile, the ABM-0702/EC1023, a linear electromechanical actuation system manufactured by **Inland Motor** in Radford, VA can be used in non-defense applications. The system actuator uses rare earth magnets and a brushless DC motor to provide high servo response. The motor is concentric to a zero-backlash recirculating ballscrew, allowing bandwidths over 35 Hz. With a supply voltage of 56-75 VDC, the system's controller can supply motor currents up to 20 amps. It provides closed loop servo control of the actuator using position feedback information. System gains are available on the system pin-outs for fine tuning of system performance. **Circle Reader Action Number 588.**

Holding optics up to four inches in diameter, **Aerotech**'s (Pittsburgh, PA) AOM360-4 motorized optical mount offers continuous 360° rotation in the elevation and azimuth axes. Vibration due to cable wrap or drag has been eliminated by connecting the cables to stationary parts of the mount, resulting in smooth translation with low jitter. Features include programming resolution of 0.001° or 1 arc second, repeatability of ±0.0021° and ±0.0035° for elevation and azimuth axes, and speeds of 40° per second. Computer control is provided by Aerotech's PC-compatible Unidex XI 1-4 axis motion controller with microstepping drives. **Circle Reader Action Number 587.**

Machinery

Hardware, Techniques, and Processes

Books and Reports

Charcoal/Nitrogen Adsorption Cryocooler

A refrigerator with no wear-related moving parts produces 0.5 W of cooling at 118 K.

NASA's Jet Propulsion Laboratory, Pasadena, California

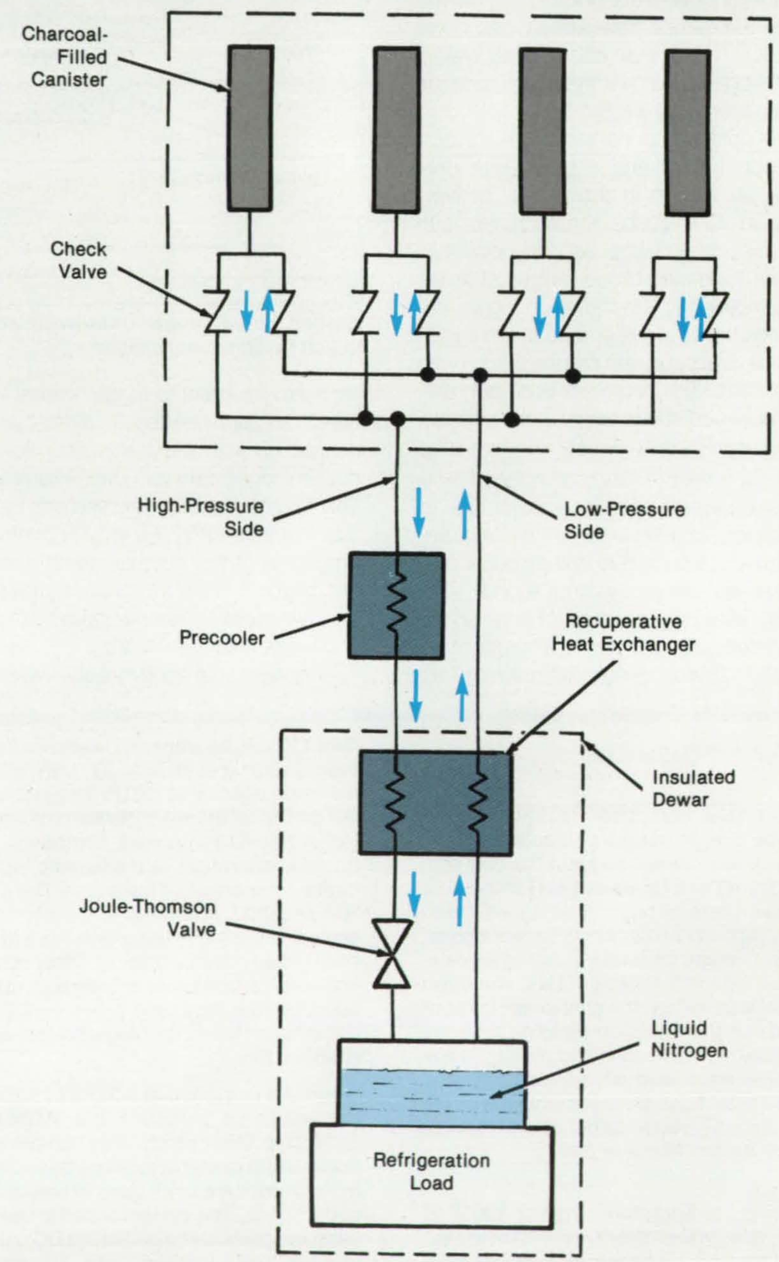
A cryogenic refrigerator powered by adsorption compressors is nearly immune to wear and generates negligible vibration. When fully developed, the refrigerator will need no electrical power, and with a life expectancy of more than 10 yr, the refrigerator could operate unattended to cool sensitive infrared detectors for long periods. In a laboratory demonstration, the refrigerator provided 0.5 W of cooling at 118 K and achieved temperatures as low as 100 K.

The cryocooler (see figure) uses activated charcoal to absorb and release nitrogen alternately. When the charcoal is cooled, it physically absorbs nitrogen. When it is heated, it releases nitrogen at high pressures.

By alternately heating and cooling four canisters filled with charcoal, the cryocooler generates a nearly continuous flow of high-pressure nitrogen. The gas flows through a precooler and a recuperative heat exchanger, then expands to low pressure through a Joule-Thomson valve, cooling to 118 K and partially liquefying as it does so. The gas returns through the heat exchanger (where it picks up heat surrendered by the inflowing gas) to the canisters for repressurization.

The only moving parts in the cryocooler are highly reliable, self-actuated check valves. The valves operate at room temperature and at low frequency (about once every 2 min).

In the laboratory demonstration, the charcoal was cooled to −30 °C by methanol flowing through a jacket surrounding the canisters. The charcoal was heated to 100 °C by electrical film heaters bonded to the canisters. The nitrogen was compressed from 320 to 810 lb/in.^{2} absolute



The **Only Moving Parts** in the adsorption cryocooler are check valves. As the charcoal is cooled in a canister, the gas pressure drops, allowing the inlet check valve to open and admit more nitrogen. When the canister is heated, the pressure rises, closing the inlet valve and eventually opening the outlet valve.

Q. **How is the material categorized?**

A. You can subscribe to any or all of the six (6) categories offered.

A. **ELECTRONICS** (includes: Electronic Systems; Electrical; Electronic Components and Circuits)
B. **PHYSICAL SCIENCES** (includes: Energy Sources)
C. **MECHANICS** (includes: Machinery; Equipment and Tools)
D. **MATERIALS** (includes: Chemistry)
E. **FABRICATION TECHNOLOGY**
F. **3-IN-1** (includes: Mathematics & Information Sciences; Life Sciences; and Pre-1976 Computer Programs. After 1975, Computer Programs have been grouped under one of the appropriate categories above.)

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1. **SUBJECT TITLE**
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   You can review the abstract of any brief on your computer. The year in which the brief was published will be displayed with the abstract. You may order the complete briefs for as little as $2.00 each, subject to ordering procedure.

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   BONUS—
   Technical Support Packages (TSP), in-depth descriptions of the technology covered by the briefs, are available from NASA for most published Tech Briefs. A TSP request form included with your Tech Brief allows you to obtain most TSP's, when available, at no additional cost.

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(2.2 to 5.6 MPa). About 150 W of input power was needed to provide 0.5-W cooling. In a fully developed unit, the input power could be reduced to below 50 W. The canisters would be cooled by small passive radiators and heated by direct solar energy or the waste heat of a power source.

A temperature of 80 K can be achieved by changing the operating pressures and adding another stage of compressors. Various other gases, such as methane, helium, and hydrogen can also be used with charcoal to achieve a wide range of cooling temperatures. The charcoal/nitrogen cryocooler can also be used as an upper stage in a cascade refrigeration system, yielding an ultimate lower-stage temperature of less than 4 K.

This work was done by Steven Bard of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 97 on the TSP Request Card.*
NPO-16786

Lumped-Parameter Representation of Wind Tunnel

A hybrid analog and digital model simulates performance.

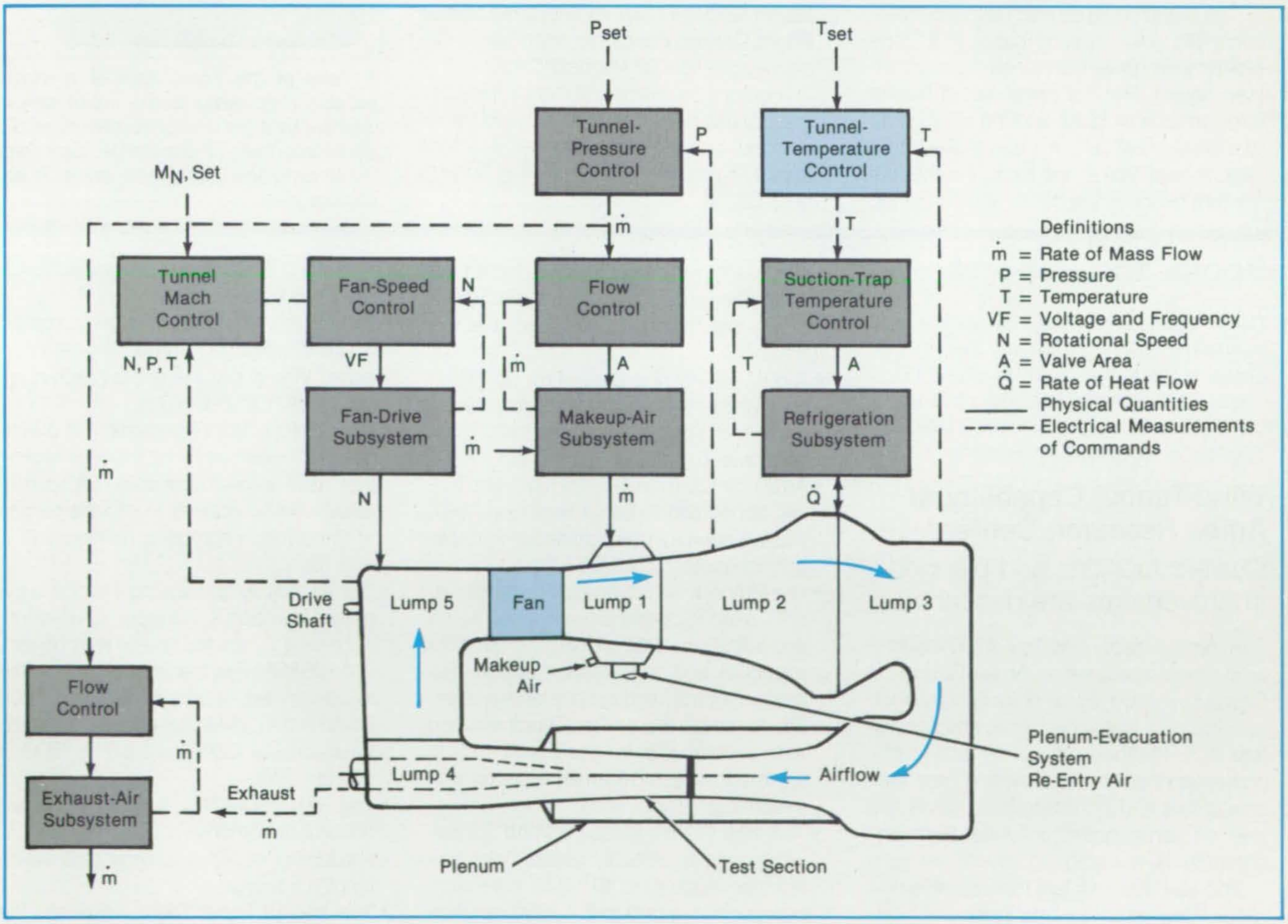
Lewis Research Center, Cleveland, Ohio

The mathematical model of a proposed wind-tunnel facility represents the wind-tunnel circuit and associated equipment in terms of lumped-parameter components. The model requires much less computational effort and computing time than would a full three-dimensional aerodynamic computer analysis of the system with many volume elements. Nevertheless, the lumped-parameter representation approximates the distributed nature of the wind tunnel well enough to simulate the steady-state and transient behavior for the analysis of proposed control subsystems and for the training of operators.

The wind-tunnel circuit is divided into five lumps (not counting the fan) governed by nonlinear equations. Integrated into the circuit model are representations of the air-supply, exhaust, refrigeration, fan-drive, and other systems (see figure), each of which is represented by a set of transfer functions.

For each wind-tunnel lump, ordinary differential equations are written for the rate of change of mass flow, mass density, and energy storage in each of two half-lump volumes: these equations are one-dimensional statements of the conservation of momentum, mass, and energy, respectively. Since the lumps are contiguous, each pair of half-lump volumes from adjacent lumps can be combined into one flow volume, in which the rates of change of mass and energy are computed. The half-lump volumes on either side of the fan cannot be combined: consequently, the five lumps give rise to six flow volumes.

The frictional pressure drop in each volume is approximated by the product of a constant coefficient, the ratio of length to diameter, and the kinetic-energy density in the volume. Auxiliary equations are used to calculate the pressures, temperatures, and mach numbers of interest at various places around the tunnel. The airflow through the fan is taken from a two-dimensional representation of the fan perform-



A **Lumped-Parameter Circuit Model** represents the wind tunnel and the associated equipment. The model can be implemented on analog or digital computers to simulate wind-tunnel performance without risk to operators or equipment.

ance as a function of the pressure ratio and the rotational speed.

The subsystem models and their controls are all implemented on two analog computers: digital equipment is used only for the initiation and verification of the analog computers and for the collection and display of data. The steady-state simulation data agreed well with performance data calculated by a detailed program for steady-state performance of the wind tunnel. The simulated dynamic response agreed reasonably well with the dynamic response predicted by a distributed, wave-equation model: the use of the lumped-parameter model would result in conservatively designed controls.

This work was done by Susan M. Krosel, Gary L. Cole, William R. Bruton, and John R. Szuch of **Lewis Research Center**. *Further information may be found in NASA TM-87324 [N86-27036/NSP], "A Lumped Parameter Mathematical Model for Simulation of Subsonic Wind Tunnels."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. *LEW-14515*

Solar Pump

Heat from the sun would move liquid; no electrical or mechanical input would be needed.

Marshall Space Flight Center, Alabama

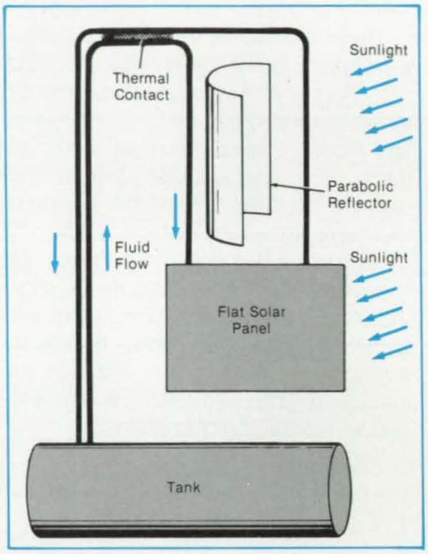
A proposed pump would move liquid by the action of bubbles formed by the heat of the sun. A tube of liquid having a boiling point of 100 to 200 °F (38 to 93 °C) would be placed at the focal axis of a cylindrical reflector. Concentrated sunlight would boil the liquid at the focus, and the bubbles of vapor would rise in the tube, carrying liquid along with them, much like the bubbles in the stem of a percolator coffeepot. The pressure difference in the hot tube should be sufficient to produce flow in a large loop.

The pump could be used with a conventional flat solar heating panel in a completely solar-powered heat-storage system (see figure). The flat panel would heat a large volume of liquid, and the solar pump would add heat to boil it and move it to a tank. A heat leak in the form of a thermal contact between the cooler liquid entering the flat panel and the hotter liquid leaving the pump would remove enough heat to reabsorb the bubbles in the liquid. The heat leak is at the highest point in the loop to ensure that the buoyancy of the bubbles does not interfere with the downward flow of liquid.

A working model, heated by a flame rather than sunlight, has demonstrated the feasibility of the concept. The model operates with a height of 3 ft (about 1 m).

This work was done by Charles Pique of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information, Circle 140 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 14]. Refer to MFS-28202.



A Tube at the Focal Axis of a vertical parabolic reflector heats liquid already warmed by a conventional solar panel. The additional heat is enough to form vapor bubbles in the liquid and pump it to a storage tank.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Wind-Tunnel Capability at Ames Research Center

Current facilities and planned improvements are described.

A report describes the $700 million wind-tunnel complex at Ames Research Center, including auxiliary support systems, test instrumentation, and special test rigs. Planned near-term facility improvements aimed at providing new test capabilities and increased productivity, as well as some potential longer-term improvements, are also discussed.

The aerodynamic test facilities at Ames range from subsonic wind tunnels to high-enthalpy arc jets. Some of these facilities are atmospheric, whereas others are variable-density facilities providing increased Reynolds-number test-range capability. Among the facilities described are the following:

- A 40- by 80-ft (12.2- by 24.4-m) closed-return wind tunnel used to test full-scale aircraft and Space Shuttle models from speeds of 0 to about 300 kn (154 m/s);
- An 80- by 120-ft (24.4- by 36.6-m) wind tunnel, scheduled to begin testing in 1987, that will have a maximum airspeed capability of about 100 kn (51.4 m/s);
- The Outdoor Aerodynamic Research Facility, used to obtain ground-based hover and acoustical data on full- or small-scale rotorcraft and vertical/short-takeoff-and-landing aircraft and propulsion systems;
- The Anechoic Hover Test Chamber, used to test rotors up to full-scale tip speeds to explore their aerodynamic, acoustic, and dynamic characteristics;
- The 12-ft (3.7-m) Pressure Wind Tunnel, which has a uniquely broad Reynolds-number range (0 to 10^7) over the mach-number range of 0 to 0.4 (This variation in the Reynolds number is achieved through changes in the stagnation pressure of the facility, currently limited to 4.5 atm (0.46 MPa) absolute;
- The Unitary Plan Wind Tunnel Complex, which enables a common model to be tested throughout the entire mach-number range from 0.4 to 3.5;
- The 3.5-ft (1.1-m) Hypersonic Wind Tunnel, a closed-circuit blowdown facility that uses interchangeable, contoured, axisymmetric nozzles to provide testing at three mach numbers, nominally 5, 7, and 10;
- The Aerodynamic Heating Facility, a hypersonic (mach 3 to mach 15) wind tunnel driven by an arc heater with powers up to 20 MW [This tunnel can be operated at stream enthalpies of 500 to 15,000 Btu/lb (1.2 to 35 MJ/kg) and at stagnation pressures of 0.005 to 5.0 atm (500 to 500,000 Pa)];
- The High-Power CO_2 Gasdynamic Laser, a combustion-driven laser capable of producing radiative energy at a wavelength of 10.6 μm;
- The 20-MW Panel Test Facility and the 60-MW Interaction Heating Facility used for studies of aerodynamic heating in the


Circle Reader Action No. 367

thermal environment resulting from the interaction of a flow field with an irregular surface;

- The Giant Planet Facility, driven by a constricted-arc heater capable of operating for about 30 s at powers up to 100 MW, used to simulate a thermal environment such as would be encountered in the Jovian atmosphere;
- The High Enthalpy Entry Facility, a scaled-up version of the Giant Planet Facility, that can operate at power levels up to 150 MW. The combined heating level that can be imposed on a test specimen is 20 kW/cm^2 — 12 kW/cm^2 convective and 8 kW/cm^2 radiative;
- Support facilities including a high-pressure air system, a balance-calibration laboratory, a propulsion-simulator calibration laboratory, and a standardized wind-tunnel data-acquisition system.

This work was done by C. T. Snyder and L. L. Presley of **Ames Research Center**. *To obtain a copy of the report, "Current Wind Tunnel Capability and Planned Improvements at NASA Ames Research Center," Circle 16 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11720.

Plasma Rocket With Hybrid Exhaust Plume

An injected sheath of neutral gas would insulate the exhaust nozzle.

A proposed plasma rocket, described in a report, would generate a hybrid exhaust plume comprising an annular layer of relatively cool neutral gas around the plasma core. The plasma and gas would intermix somewhat, providing a gradual radial transition between the two. The amount of gas injected can be adjusted to control the propulsive efficiency; the relatively cool gas boundary layer at the surface of the nozzle would insulate the nozzle from the high plasma temperature.

The thrust of a rocket is proportional to both the mass-flow rate and the square root of the temperature of the exhaust plume. Chemical-fuel rockets depend on high mass flow rates rather than extreme temperatures to achieve high thrust, but the mass of fuel required limits the burn time. On the other hand, existing plasma thrusters achieve higher temperatures but have limited mass-flow rates. Furthermore, the exhaust temperature must be kept below the maximum operating temperature of the nozzle material.

The proposed hybrid-plume rocket concept would remove the limit on the plasma temperature and at the same time provide increased adjustable mass flow. The engine would include a plasma generator (for example, a magnetoplasma dynamic generator) and a magnetic containment and power-boosting system with one or more focusing and confining "baseball" coils and solenoid coils. Microwaves at the plasma cyclotron frequency would supply additional heat to the plasma.

Upstream of the nozzle entrance, the plasma would be kept away from the duct by the magnetic field. Cool hypersonic neutral gas would be injected into the flow through inlets around the periphery at the nozzle entrance. Collisions between the gas and the plasma would detach the plasma from the magnetic field lines. The plasma would then move preferentially in the direction of lower density; namely, downstream and slightly toward the axis.

The hybrid-plume rocket produces a variable specific impulse. Furthermore, by adjustment of the ratio of exhaust plasma to neutral gas, the propulsive efficiency can be maximized over the range of speeds of the rocket to conserve fuel. The engine can thus be tuned optimally at all phases of the flight. Calculations show that a hybrid-plume rocket in outer space can travel at least three times the distance of a chemical-fuel rocket in the same time and with the same initial amount of fuel.

The terminal velocity of the hybrid-plume rocket can also exceed that of a comparable chemical-fuel rocket. Although the chemical-fuel rocket accelerates faster at first, it uses up its fuel sooner. The hybrid-plume rocket develops less thrust at first but burns longer and more efficiently, eventually overtaking the chemical-fuel rocket.

This work was done by Franklin R. Chang of **Johnson Space Center**. *To obtain a copy of the report, "Hybrid Plume Plasma Rocket," Circle 129 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 14]. Refer to MSC-20476.

Analysis of Solar Electrical and Thermal Systems

A computer program analyzes the areas, weights, and costs of five basic systems.

A report describes a computer program for the parametric analysis of alternative ways of generating heat and electrical power on a satellite or spacecraft. The program, called the Solar Space Power Analysis Code (SOSPAC), examines the changes in area, weight, and cost of the generator system for changing conditions, in particular for changes in the ratio of thermal to electrical outputs.

SOSPAC applies to the following five types of generator systems:

1. Photovoltaic array;
2. Parabolic dish for generating electricity only;
3. Photovoltaic array for electricity and parabolic dish for heat;
4. A single dish for electricity, with excess power used for heat; and
5. A dish for electricity and another for heat.

By the insertion of a few statements, the program can be modified easily to add new combinations of photovoltaic and parabolic-dish systems.

The inputs to the program are data on the required electrical and thermal power, Sun and shade durations, distance to the Sun, and weights and costs of subsystems and components. The program structure allows elaboration of subroutines for component and subsystem performance without changes in the main code.

The report outlines the SOSPAC execution procedure and presents a sample set of input data. It gives an example of mass and area calculations for the sample data for each type of generator system and illustrates the results with a variety of charts.

This work was done by M. Kudret Selcuk of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Development of a Computer Code to Analyze Solar Thermal/Electric Space Power Options," Circle 148 on the TSP Request Card.*
NPO-16844

Linearization of Robot Manipulators

Four nonlinear control schemes are equivalent.

A report discusses the theory of nonlinear feedback control of a robot manipulator, with emphasis on control schemes that make the manipulator input and output behave like a decoupled linear system. This approach, called "exact external linearization," may contribute to efforts to control end-effector trajectories, positions, and orientations.

The discussion begins with a review of the rigid-body dynamics of an n-link manipulator. It is shown that the end effector evolves according to a highly nonlinear, coupled set of equations involving first and second time derivatives, the end-effector contact forces, and the control inputs. The problem then becomes one of finding a feedback control law that, in effect, masks the internal nonlinearities of the system in that it makes the input/output dynamics behave according to a set of decoupled linear equations in the end-effector coordinates.

There follows a discussion of general linearizing feedback laws. The exact linearizing controllers described in this section are shown to be equivalent to those ob-

tained by the application of any of four previously developed techniques; namely, the computed-torque, resolved-acceleration-control, general nonlinear decoupling, and differential-geometric techniques.

The author states that the exact linearizing techniques are general enough to apply to redundant and actuated serial-link manipulators subject to measurable reaction forces and torques on their end effectors. All the exact linearizing controllers can be derived from a theoretical perspective that has its basis in resolved acceleration control. This perspective makes it possible to speed up the control computations by using the Newton-Euler recursion to compute the inverse dynamics for both unactuated and actuated manipulators.

This work was done by Kenneth Kreutz of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "On Nonlinear Control for Decoupled Exact External Linearization of Robot Manipulators," Circle 114 on the TSP Request Card.*
NPO-16911

New Products

Keep the data in and the dirt out. **Linseis** (Princeton, NJ) models L 2005 Series 1-6 channel recorders are available with a locking gasketed see-thru door for use in industrial process environments. Inputs are from the rear of the 19-inch rackmountable instrument. Modularity allows for measurement of mV/V, temperature, current, ohms, RTD and strain gauge. 50 standard modules are in stock and custom modules can be designed for special applications. **Circle Reader Action Number 584.**

A new general purpose piezoelectric pressure sensor is well suited for high volume, low-cost applications—wherever gauge, absolute or differential pressure must be measured. The **IC Sensors'** (Milpitas, CA) Model 410 DIP sensor uses a 5-pin open bridge resistor format, allowing excitation with either a voltage or current source. The Model 410 is pin-compatible with the IC Sensors 1210 series, the Motorola MPX and the SenSym SPX and SX series. The sensor has an accuracy of ±0.1%. Typical output span on the media-compatible sensor is 100mV. **Circle Reader Action Number 586.**

Excess flow valves are the fluid system equivalents of circuit breakers. A fusion-encased excess flow valve, with no seals exposed to the atmosphere, is now available from **Nupro Company**, Willoughby, OH. The design assures absolute containment of gas in case of major leaks, ruptures or component failures in the fluid system. The valve responds instantly to pressure drops of less than one PSI, shutting down the system. Its pressure-enhanced poppet-to-seat seal maintains leak-tight shut off until intentionally reset. Other features include excellent purgeability, low internal volume and smooth internal finishes for clean operation. Service ratings are 3000 PSI and -20° to 450°F. **Circle Reader Action Number 585.**

Wedge Joints for Trusses

Structures could be assembled rapidly with simple hand tools.

Lyndon B. Johnson Space Center, Houston, Texas

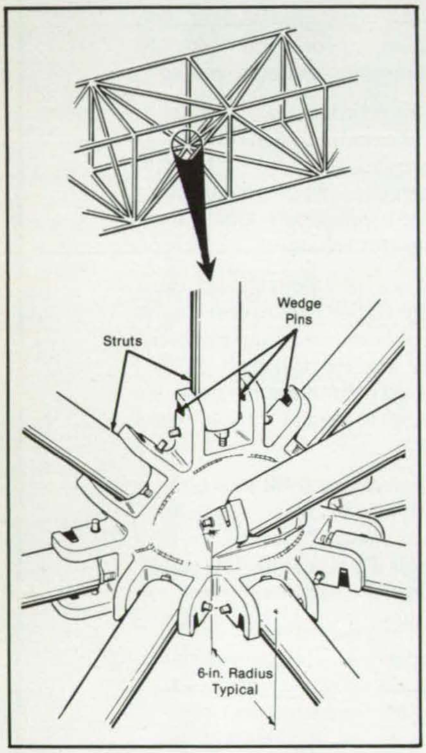


Figure 1. A **Lightweight Structure** would be assembled from tubular struts joined at nodes by wedge pins that fit into mating slots.

Proposed locking wedge joints would enable the rapid assembly of lightweight beams, towers, scaffolds, and other truss-type structures. At each joint, a wedge pin integral with a tubular strut would be held securely in V-shaped slots in a bracket on a node (see Figure 1).

Wedge pins would be installed at the ends of each tubular strut during manufacture. If the strut is to be made of graphite/epoxy composite, as suggested at the left of Figure 2, the pins can be installed before curing the epoxy. After the cure, the wedge faces can be machined to close tolerances for correct strut length, alignment, and seating in the V-shaped slots.

The assembly of a joint would begin with the insertion of the wedge pin into the matching V-shaped slots (also shown in Figure 2). With the help of a specially shaped tool, the assembler would push on (and slightly deform) the end of the strut, forcing the wedge securely into the slots. A spring-loaded primary pawl would then engage the end of the strut to hold it in place. A spring-loaded secondary pawl would intrude a short distance into the inside of the hollow strut to provide additional wedging force and redundant locking.

The wedging action should contribute to the precision of the joints, thereby helping to correct truss misalignments. The wedging force applied by the pawls should assure lifetime wedging with no joint looseness.

This work was done by Kenneth E. Wood of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 90 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Johnson Space Center [see page 14]. Refer to MSC-21072.

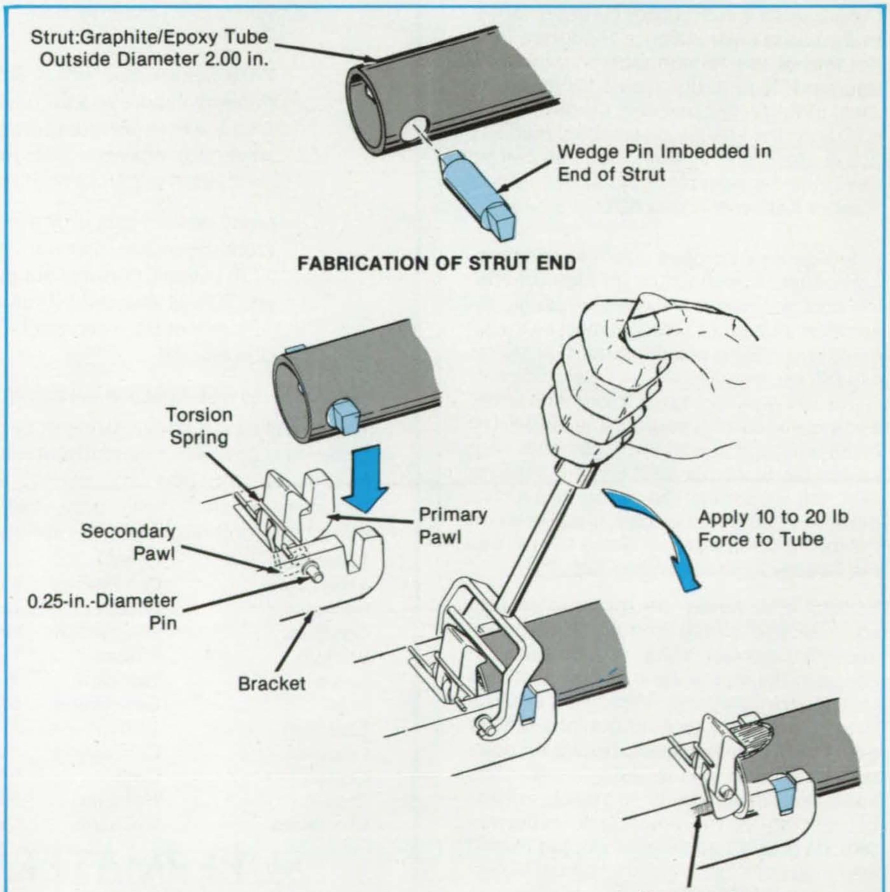


Figure 2. This **Joint Would Be Assembled Rapidly** by seating the wedge pin in the V-shaped slots and deforming the end of the strut until the primary pawl engages it.

Punching Holes in Thin Metals

Edges are clean and sheets remain flat.

Lyndon B. Johnson Space Center, Houston, Texas

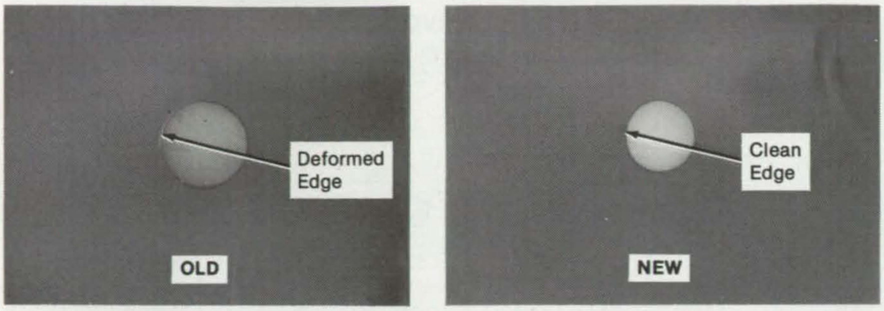


Figure 1. **Holes Were Punched** in nickel-alloy sheet 0.003 or 0.004 in. (0.076 or 0.10 mm) thick by a conventional punch and die (left) and by the new tool (right).

A simple punching tool has been used to make holes in thin metal sheets, without the burrs and edge deformations that accompany the use of conventional punch-and-die sets (see Figure 1). The tool can be used on such materials as stainless steel, nickel alloys, beryllium, copper, and aluminum, in thicknesses of 0.002 to 0.010 in. (0.05 to 0.25 mm). With the new punch, the hole size can be held to a tolerance of ±0.001 in. (0.025 mm).

Instead of a conventional die, the tool (see Figure 2) includes a clamp made of two 3/32-in.-(2.4-mm-) thick titanium plates. A hole is drilled and reamed simultaneously through both plates to produce congruent holes of the size and shape to be punched. To maintain the alignment of the punch holes, two dowels are press-fit into one plate and have a slip fit in the other.

Instead of a conventional metal punch, the tool includes a rubber punch with a hardness of Shore durometer 45; the punch fits in a holder on an arbor press. The punch is wider than the hole. With the thin metal sheet placed between the plates on the arbor press, the punch pushes down on the plates, clamping the three layers together. As the pressure increases, the rubber extrudes into the hole, eventually reaching and pushing out the exposed portion of the sheet. When the pressure is removed, the rubber retracts from the hole, resuming its original shape.

This work was done by Richard Garcia, Derrell Foster, and Valentino Miranda of Rockwell International Corp. for **Johnson Space Center**. *No further documentation is available.*
MSC-21134

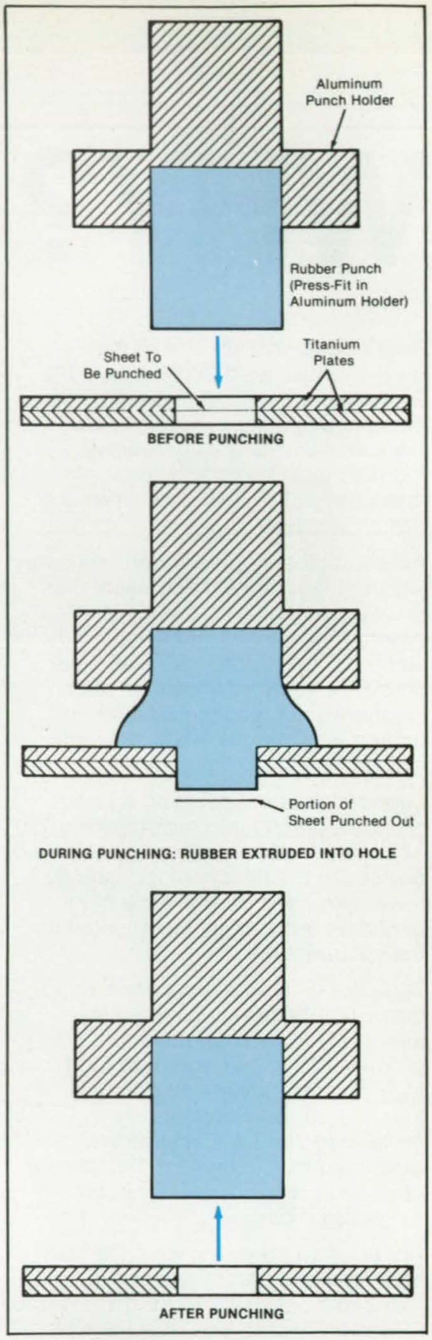


Figure 2. The new **Punching Tool** includes a rubber punch that extrudes into the hole in the top plate, pushing out the exposed portion of the clamped metal sheet.

Device Applies Films to Optical Elements

The resulting coatings are free of wrinkles and air bubbles.

Ames Research Center, Moffett Field, California

A clamping device applies a protective or antireflective dielectric coating to lenses or other optical elements. An alternative version of the device applies a thin sheet of a dielectric film to a ring or stretches it for clamping in a holder to form a pellicle or beam splitter.

Although a variety of dielectric films adhere well to optical elements, it is difficult to obtain a smooth, flawless surface. The imperfections come from wrinkles in the plastic and from residual air bubbles. These defects are avoided by the new apparatus, which uniformly stretches the dielectric films in a radial direction and creates a vacuum between them before they are thermally bonded to the optical element.

As shown in the figure, the device includes a pair of outer plates, a polished inner plate, guide pins for alignment, and bolts and wing nuts for squeezing the plates together. Each of the outer plates has a conically tapered (about 10° angle) surface extending radially from a shoulder. The conical surface supports a heat-resistant elastic O-ring. The inner plate has a central hole for the optical element to be coated. Soldered in a groove in this plate is a hypodermic needle with an outer coupling that connects to a vacuum system that removes air between the dielectric films.

In a typical coating operation, holes corresponding to the circular bolt and pin pattern are first melted in the sheets of dielectric material, using a soldering iron and a template. The optical element to be coated is then placed in the central hole

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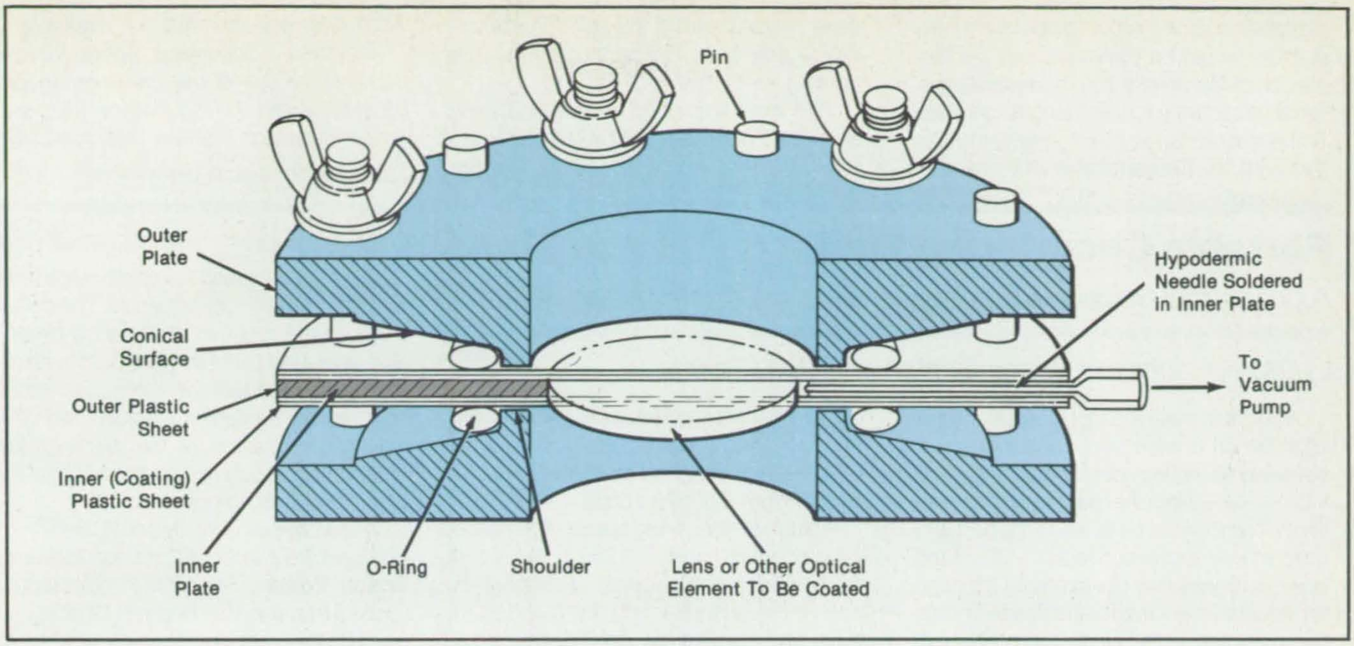


The **Optical Element To Be Coated** is clamped between inner sheets of the coating material and outer sheets of high-melting-point plastic. Tightening the wing nuts causes the O-rings to move outward, stretching the plastic sheets.

and sandwiched between two inner sheets of the coating material (for example, polyethylene). An outer sheet of a plastic with a higher melting temperature [for example, Mylar (or equivalent) polyethyleneterephthalate] is placed between each outer plate and the inner coating sheet.

Tightening the wing nuts causes the upper and lower O-rings to roll outwardly because of the tapers of the outer plates. The outward motion of the rings stretches the dielectric films radially outward. The films are observed to ensure that they are being stretched evenly and that all wrinkles and air bubbles are removed.

Next, the assembled film-application device is placed in an oven and evacuated. The temperature is raised to the required level, which for polyethylene coating is 73°C (slightly below its melting point). After approximately one hour, the thermal bond will have been made, and the vacuum and the oven are turned off. After the device has cooled, it is disassembled, and the outer dielectric is peeled off the coated element. If more than one layer of polyethylene is applied, each subsequent layer reduces the flaws of the previous layer.

To make a pellicle, the central plate is omitted, and a single dielectric film is stretched between the outer plates. When all wrinkles have been removed from the sheet, it is bonded to a pellicle holder and then cut free.

This work was done by Gordon C. Augason of **Ames Research Center**. *For further information, Circle 100 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11611.

Filament-Winding Technique for Concave Parts

A dummy mold and vacuum bagging yield accurate part girth.

Ames Research Center, Moffett Field, California

A proposed method of filament winding would facilitate the accurate fabrication of fiber/matrix composite parts having closed sections with concave surfaces. With this method, parts that had to be laid up by hand can now be wound with filaments: this reduces the time and cost of fabrication and improves the quality of the parts.

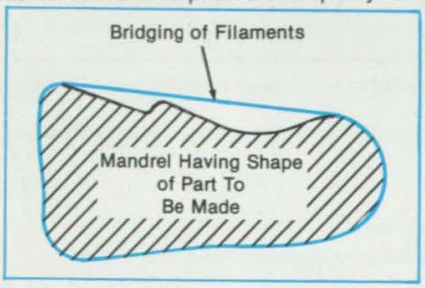


Figure 1. **Bridging** results when filaments are wound on a part with concave surfaces.

As shown in Figure 1, the conventional technique of filament winding on a mandrel with concave surfaces results in bridging of the filaments across the concave regions. This yields an incorrect part shape and girth, which could prevent the part from mating properly with another part, or otherwise prevent the part from functioning properly. Consequently, either the bridging is tolerated or else the composite material has to be applied manually in a procedure that is time consuming and costly.

As shown in Figure 2, the new method would involve a second (dummy) mandrel, which would be attached to the concave regions of the mandrel having the shape of the part to be covered. The mandrel could be constructed as a solid tool or as an inflatable part to ease removal prior to bagging. The second mandrel would be designed to have a convex winding surface, the cross-sectional path length of which is identical to the cross-sectional path length of the covered concave surface (i.e., in the figure, path A = path B).

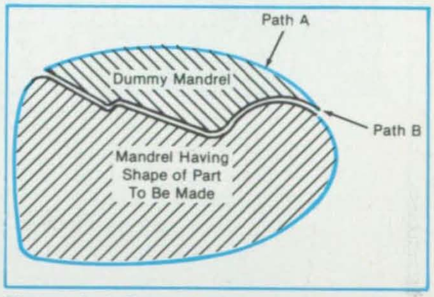


Figure 2. A **Dummy Mandrel With a Convex Outer Surface** is added to the mandrel having the shape of the part to be made. The outer dummy surface has the same perimeter as that of the covered concave portion of the first mandrel.

The filaments would be wound around the two-mandrel assembly. Following

completion of the winding operation, the dummy would be removed, and the filaments or filament/matrix composite material would be vacuum bagged onto the first mandrel. Since the filament length is just right, the filaments settle into the concave regions, giving the part the correct shape and girth. The part could then be cured.

This work was done by Donald Carter and David Schmaling of United Technologies Corp. for **Ames Research Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel. Ames Research Center [see page 14]. Refer to ARC-11672.

Portable Chamfering Tool

A power tool machines precisely onsite.

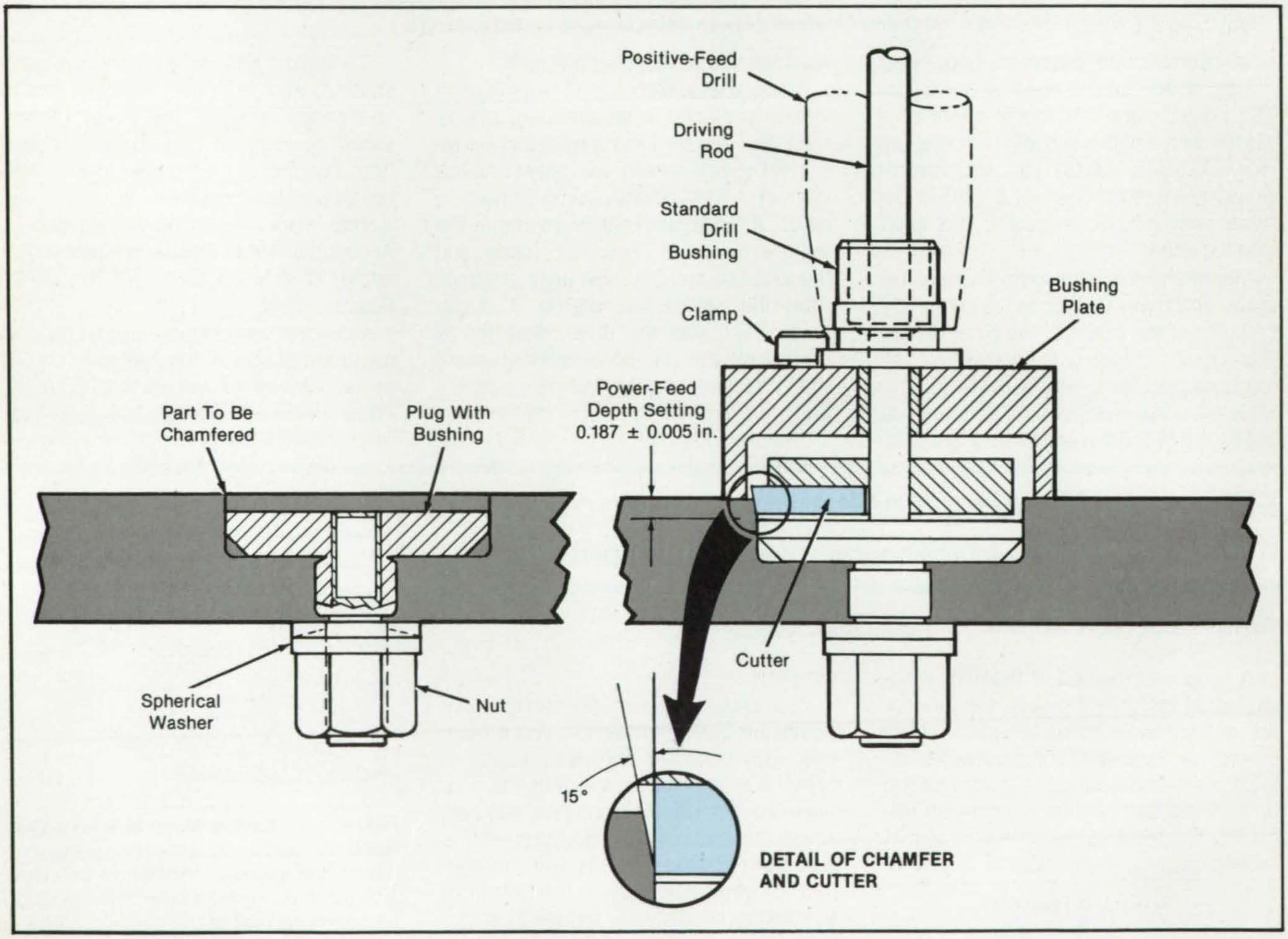
Lyndon B. Johnson Space Center, Houston, Texas

A portable machine tool precisely cuts a chamfer on a valve seat. With the tool, a delicate machining operation can be done without removing the part to a machine shop. The tool can be taken to the part and used wherever pressurized air and electric power are available. For example, it is used on the umbilical valve for the Space Shuttle external tank in the clean room in which the valve is assembled. It can be adapted for operations in aircraft, ships, land vehicles, and industrial machinery at sites remote from machine shops.

A plug with a bushing is inserted into the valve opening, which is 3.250 in. (8.26 cm) in diameter (see figure). The plug is secured by a washer and nut. It serves to guide and stabilize the rod that drives the cutting tool.

The rod is installed in a positive-feed drill when the feed is fully retracted. The cutter is set to the required chamfering dimension, and a pin 0.187 in. (4.75 mm) in diameter is inserted through the cutter holder and the rod. Fastening the cutter with the pin ensures control of the depth of the chamfer and positive retraction of the tool when the job is complete.

This work was done by Leo A. Berson of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 91 on the TSP Request Card. MSC-21087*



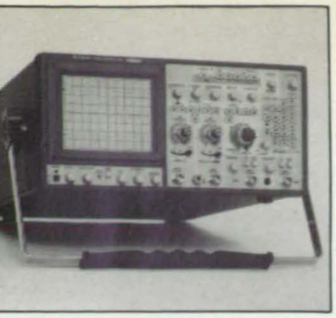
The **Plug and Bushing** nest in the bore to be chamfered. They guide and steady the cutter rod as it cuts a 15° chamfer on the top edge of the bore.

Laser Scanner for Tile-Cavity Measurement

Irregular surfaces are mapped and digitized for numerical-control machinery.

Lyndon B. Johnson Space Center, Houston, Texas

A fast, accurate laser scanning system measures the size and shape of a cavity without making any physical contact with the cavity and its walls. The measurements are processed into control signals for the numerically controlled machining of a tile



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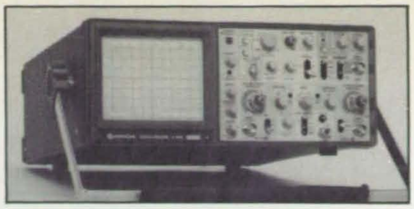

Hitachi CRT Readout Oscilloscope V-680 60MHz

Small, compact, 6-in., screen readout oscilloscope. Combines economy with a wide range of capabilities. Features 3 channels, 6 traces, delayed sweep and CursorMeasurement™ voltage and time difference frequency... panel settings, Simultaneous display of both main and delayed sweep, TV sync trigger, variable holdoff. List: $1490.

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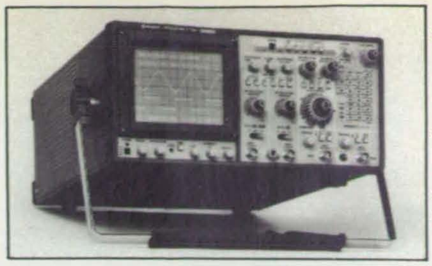

Hitachi CRT Readout Oscilloscope V-1100A 100MHz

ScreenWriter™, CursorMeasurement™ with GroundReference™ displays, and delayed sweep are three of the important features offered. Others include: 4 channels and 8 traces, 6-in. screen, built-in DVM and frequency counter (3 digit, 40 Hz resolution). List: $2490.

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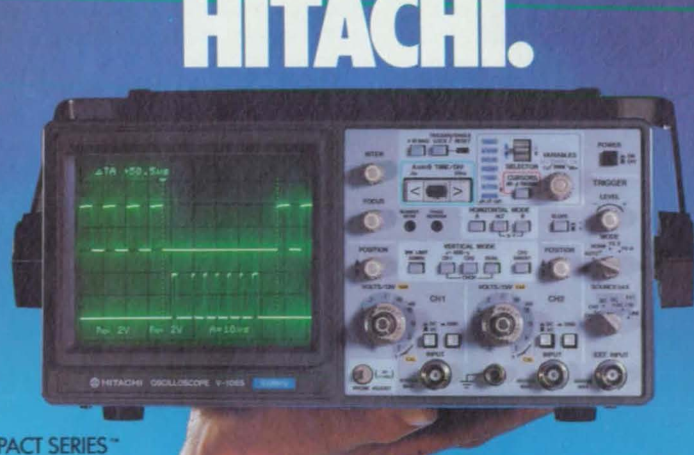

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Auto range of sweep time	✓	✓	✓	✓
Trigger lock	✓	✓	✓	✓
Peak-to-peak auto trigger	✓	✓	✓	✓
Trigger signal output	✓		✓	
Three year warranty	✓	✓	✓	✓
Price	$1795	$1495	$1395	$1095
Weight/Dimensions	13 lbs./10.8"W × 5.1" × 14.2"D			
CRT Size	8 × 10 cm			

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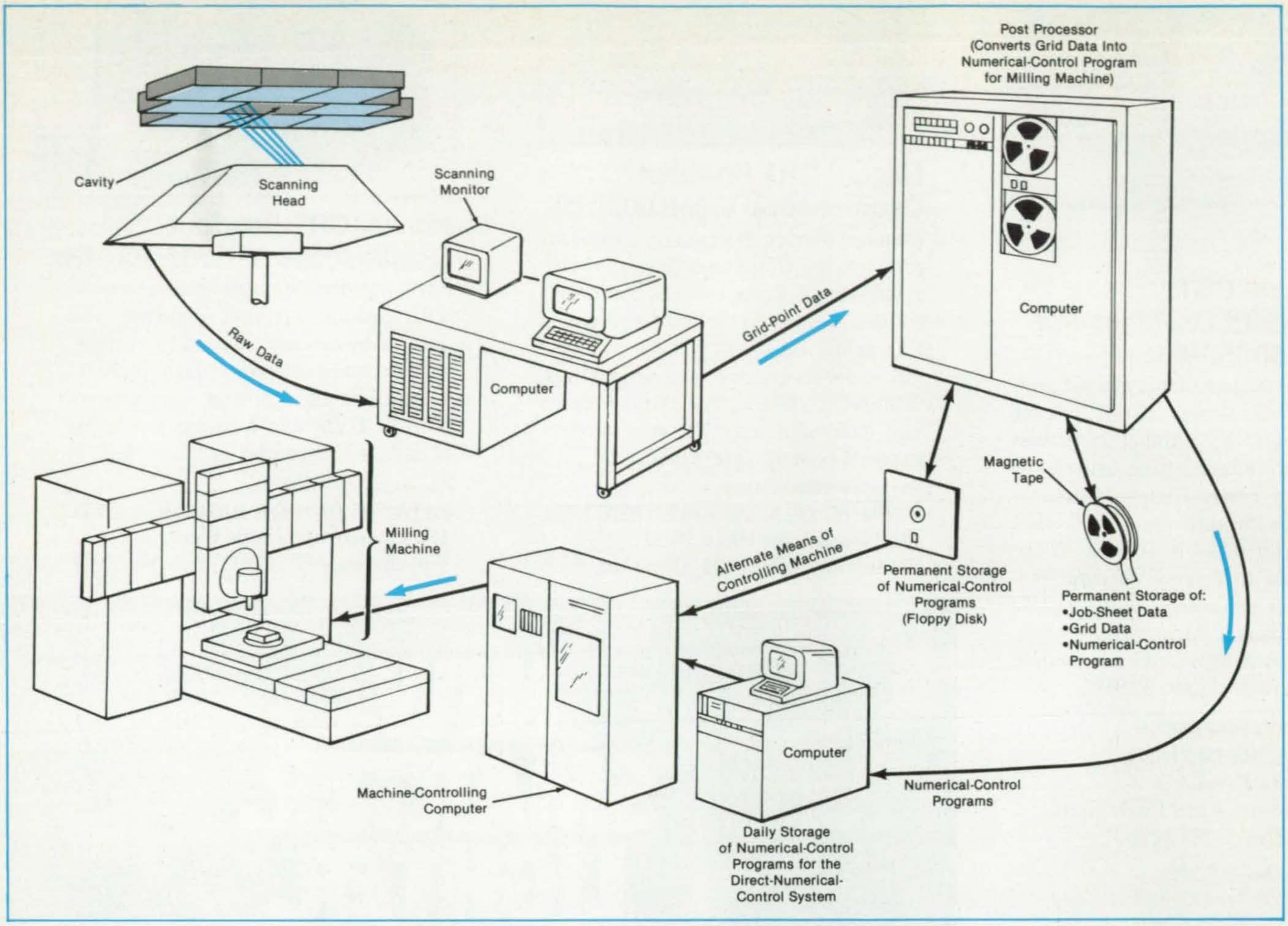
Circle Reader Action No. 516



The **Laser Scanning System** generates a map of grid points representing a cavity and a portion of the outer surface surrounding the cavity. The map data are used to control a milling machine, which cuts a tile or block to fit in the cavity.

or block to fit the cavity. Other likely applications for this system include noncontact surface measurements, robotic vision systems, and inspection of machined and sheet-metal parts.

The system (see figure) includes a scanning head (consisting of five sets of laser/camera pairs), a scanning control computer, a television monitor, and an operator terminal. A 50-ft- (15-m-) long power, data, and control cable enables the scanning head to be repositioned for different measurements.

The laser beam is directed in front of the camera and sweeps across the cavity walls and the adjacent outer surface. The measurement data travel through the cable to a computer where they are translated into positional coordinates. Altogether, the system thus generates the coordinates of 7,000 points to map the surface in about 50 s. In addition, the system can map the missing portion of the outer surface at the cavity opening by mathematical extrapolation from the adjacent outer surface. The grid-point data are fed into a postprocessor, where they are translated into the numerical control language understood by a milling machine.

This work was done by Stanley Y. Yoshino, Donald H. Wykes, George R. Hagen, Gene E. Lotgering, Michael B. Gaynor, Paul G. Westerlund, and Thomas A. Baal of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 68 on the TSP Request Card. MSC-21136*

Making Optical Correctors by Diamond Turning

An rms surface error of only 0.075 wave has been achieved.

NASA's Jet Propulsion Laboratory, Pasadena, California

The Large Optics Diamond Turning Machine (LODTM) at Lawrence Livermore National Laboratory has been used to make highly amorphic reflecting wavefront-corrector plates with an rms difference between the desired and the measured reflector surfaces of only 0.075 wave. The measured errors correspond to one standard deviation of the uncertainties in the digitization and reduction of interferograms of the surface. Thus, it appears that the accuracy of the LODTM-generated surface exceeds the current ability to measure it.

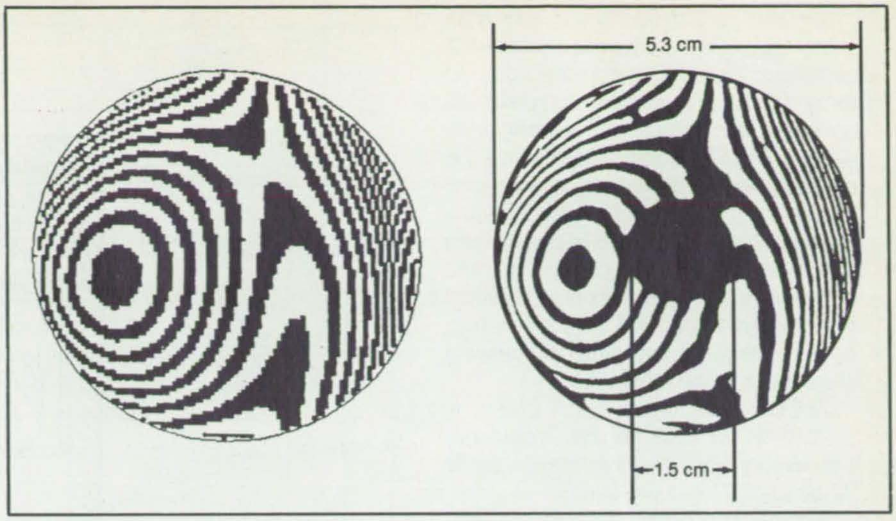
This work demonstrates the feasibility of single-point diamond turning for the manufacture of generalized wavefront-control surfaces or other unusual surfaces desired by optical designers. The maximum departure of the diamond-turned corrector surface from the nearest regular surface is set by the dynamic range and acceleration capabilities of the LODTM in controlling the motion of the diamond tool. The LODTM has the acceleration, the precision of motion, and the computer control system necessary to make an amorphic surface to 1/20-wave accuracy.

Although optical designers have explored many asymmetric optical systems, few such designs have been built because of the difficulties of manufacturing and testing such surfaces when traditional

grinding is used. The effect on performance of including an appropriate asymmetric surface can be striking: one design for a decentered Schmidt/Cassegrain system shows a reduction in rms spot radii by a factor of 3 across the field when an asymmetrical correcting surface is included.

In this experiment, two wavefront-corrector plates and one optical flat were turned on 2-cm-thick Super-Invar™ substrates with 13-percent electroless nickel plating 4 to 6 mils (0.1 to 0.15 mm) thick. As shown in the figure, the calculated and measured corrector-plate surfaces match closely.

This work was done by Aden B. Meinel, Marjorie P. Meinel, and John E. Stacy of Caltech for **NASA's Jet Propulsion Laboratory** *and Theodore T. Saito and Steven R. Patterson of Lawrence Livermore National Laboratory. For further information, Circle 105 on the TSP Request Card.*
NPO-16918



The **Wavefront-Corrector Interferogram,** as calculated from the equation of the corrector surface, is shown on the left. The measured interferogram of the diamond-turned surface (right) shows excellent agreement with the design. (The black disk in the center of the measured interferogram is due to a hole in the center of the plate.)

Supports for Wires Soldered to Pins

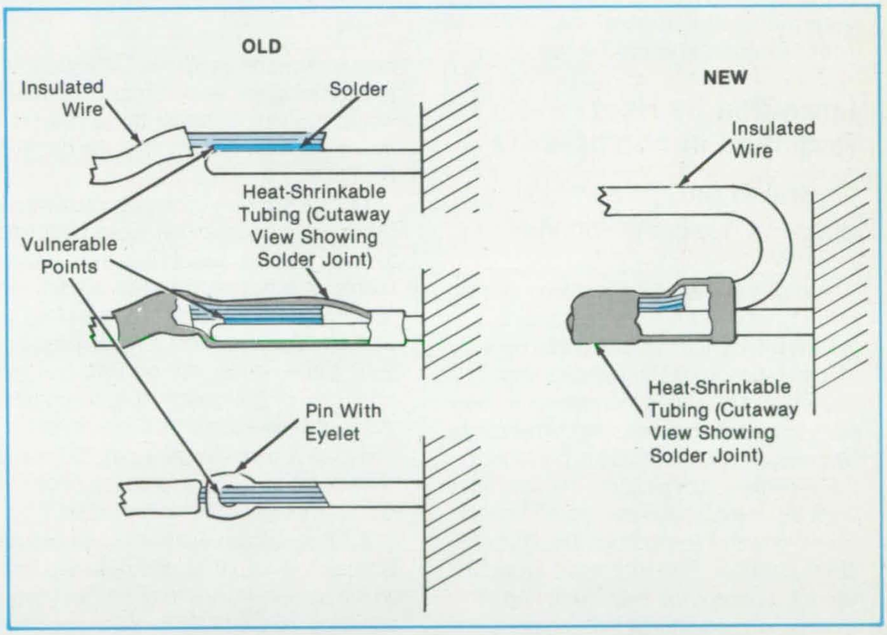
Stress concentrations are reduced by reorienting wires.

Marshall Space Flight Center, Alabama

Wire connections susceptible to damage from handling or vibration gain additional support with a new bonding configuration. Ordinarily, the soldered joint between a wire and a terminal pin is prone to fatigue cracking at the terminus of the solder fillet. In the new configuration, the wire is oriented to minimize stress in this critical region.

The direction in which the wire approaches the pin is reversed. The wire is given a U bend so that it joins the pin from the connector side instead of from the free end (see figure). The wire is soldered to the pin, then covered with a sheath of heat-shrinkable tubing. The terminal pin acts as a splint for the vulnerable section of wire next to the solder fillet.

This work was done by Arthur J. Hill of Rockwell International Corp. **Marshall Space Flight Center.** *No further documentation is available.*
MFS-29171



The **New Solder-Joint Configuration** provides support for the part of the wire most susceptible to damage from handling or vibration — the part next to the solder joint. The reversal of the wire and the heat-shrinkable tubing reduce the stress in this region.

High-Density-Tape Casting System

A centrifuge packs solids from a slurry into a uniform, dense layer.

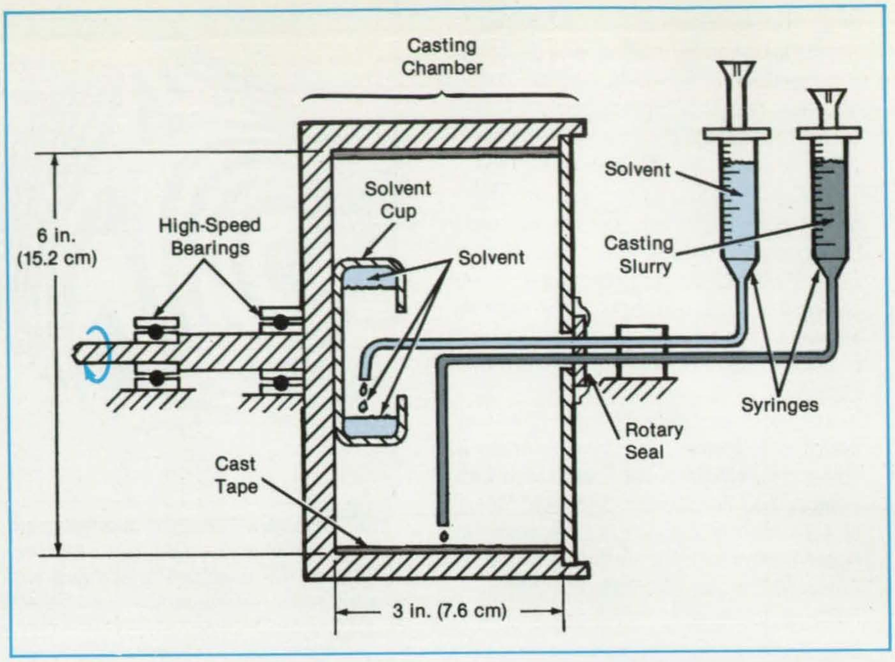
NASA's Jet Propulsion Laboratory, Pasadena, California

Tapes cast from slurries by a new centrifugal system are more densely packed and uniform than tapes cast in the conventional manner by spreading slurries onto flat surfaces to dry. Because the centrifugal packing forces used are several orders of magnitude larger than gravity, the new system produces tapes of nearly theoretical packing density. The centrifugal system can be used to cast thin tapes for capacitors, fuel cells, and filters, for example.

The new system (see figure) uses a rotating drum as a centrifuge to enhance the packing of the particles from the slurry. To delay drying until casting is complete, vapor pressure is maintained by placing extra slurry solvent in a coaxial cup inside the casting drum. After casting is complete, the liquid is removed and the vapor is vented to allow the membrane to dry. Binders from the slurry coat the solid particles and hold them together. The dry tape is peeled from the inside of the drum for sintering, heat treating, or any other processing steps that may be required.

This work was done by Earl R. Collins, Jr. of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 22 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA's Jet Propulsion Laboratory [see page 14]. Refer to NPO-16901.



The **Cylindrical Rotary Casting Chamber** is mounted on high-speed bearings and connected to a motor (not shown). The liquid for vapor-pressure control and the casting slurry are introduced from the syringes through the rotary seal. During the drying step, the liquid and vapor can be vented through the feed tubes or other openings. Laminated tapes can be produced by adding more syringes to cast additional layers of different materials.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Levitation by Heat Radiation in Microgravity

Radiation pressure would push samples into position.

A report presents calculations relating to the feasibility of a proposed heating-and-levitating technique for use in microgravity. In a material-processing system based on this technique, a specimen would be heated to the required processing temperature by thermal radiation, and the pressures of the radiation impinging on the specimen from different directions would be controlled to push the specimen toward the desired position. The technique would be used in spaceborne manufacturing processes and experiments that require levitation in a vacuum to prevent contamination of any kind from reaching the specimens.

The heating-and-levitating apparatus would include six heat sources — as an example, electrically heated tungsten filaments with reflectors. Each heat source would be centered on one of the faces of an imaginary cube, facing inward. The difference in radiation pressure on the opposite faces of the specimen — and, therefore, the acceleration of the specimen along each axis of the cube — would be controlled by turning heat sources on or off or by increasing or decreasing the difference between the electrical powers supplied to the oppositely facing heat sources on each axis. During a typical heating process, an automatic subsystem would repeatedly adjust those powers to maintain the specimen near the center of the cube.

Using the theory of black-body radiation, preliminary calculations were performed to estimate the capabilities and requirements of a typical levitation system. The specimen was assumed to be a glass ball of 1-cm diameter with a mass density of 2.72 g/cm^3, emissivity of 0.30, and heat capacity of 0.2 cal/gK. Each tungsten-filament heat source was assumed to be coiled to a diameter of 1 cm, to have an emissivity of 0.35, and to be heated to 6,000 °F (3,589 K) when turned on.

If the specimen were at a typical room temperature of 20 °C, the radiation force on the sample from one of the heat sources would be 0.044 dyne. If the specimen were at a processing temperature of 2,000 °C, the radiation force would be 0.037 dyne. In both cases, the radiation force is more than enough to overcome the microgravitational force of 0.014 dyne that would occur in a typical field of 10^{-5} times the average gravitation at the surface of the Earth.

In a typical process, the glass ball might be irradiated while it is kept at the center by turning up one heat source at a time (the one toward which the sample is drifting). The black-body calculations show that it would take about 15 minutes to raise the temperature of the sample from 20 °C to 2,000 °C. Thus, it appears feasible to heat and position a specimen by thermal radiation alone.

This work was done by Philip I. Moynihan of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Levitation of a Test Sample in Microgravity by Radiation Pressure," Circle 81 on the TSP Request Card. NPO-17022*

Effects of Control Parameters on a Robot Welder

Gains and weighting factors in a vision-based controller are evaluated.

A report describes a study of the trajectory control in a vision-based robotic welder. It covers an evaluation of the user-programmable parameters that dictate the control response to a perceived error in tracking the weld seam.

The welder uses illumination from the welding arc for vision-based tracking of square butt joints viewed through the welding torch. The system uses a proportional-integral-differential control algorithm. The trajectory-control procedure begins with detection of the weld joint. Confidence in the collected image is quantified and must be greater than a programmed threshold for correction to occur. If the decision is to track an image feature, the present error is calculated as the distance between the joint position and the center of the elec-

trode. Once the present error is calculated, it is averaged with preceding values by a recursive technique.

In the evaluation, a controlled disturbance was provided by welding on straight-line square butt joints using a programmed path with a ramp offset and two step offsets. The tracking accuracy was measured at increments along the weld path, and the collected data were statistically reduced to three values for each weld. Two of the values measured accuracy and the third measured stability.

The measurements showed that increasing the proportional gain increased the ability of the system to correct for abrupt offsets. However, the overall accuracy, as expressed by the root-mean-square error, tended to decrease when gain was raised beyond a certain level because of the consequent decrease in stability. Varying the differential gain caused little change in the control response over a wide range.

Increasing the integral gain tended to reduce the stability of control. Increasing the seam data average weight (an exponent in the weighting factor) also reduced stability.

This work was done by K. J. Gangl and J. L. Weeks of Rockwell International for **Marshall Space Flight Center**. *Further information may be found in NASA CR-178538 [N80-16587/NSP], "Influence of Control Parameters on the Joint Tracking Performance of a Coaxial Weld Vision System."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. The report is also available on microfiche at no charge. To obtain a microfiche copy, Circle 56 on the TSP Request Card.
MFS-28162

Study of Silicon-Web Growth

Previously accepted concepts appear to be inadequate.

A study of the dendritic-web growth of single-crystal silicon has cast doubts on previously accepted physical concepts of the process. Despite more than 25 years of investigation, dendritic-web growth is not yet commercially viable for the production of single-crystal silicon for solar photovoltaic cells. Progress is impeded by the lack of understanding of the many phenomena involved. Of particular concern are the thermal conditions in the melt around the growing solid. It now appears that previous assumptions regarding temperature distributions were incorrect, partly due to an erroneous published interpretation of the pioneering work of Czochralski.

In the dendritic-web process, the solid web of silicon is pulled from the melt through a narrow slot in a lid that covers the silicon melt. Holes at the ends, which give the slot a "dog-bone" appearance, allow increased local thermal radiation from the melt to impose a more desirable spatial temperature distribution. Growth is initiated by placing a seed crystal at the center of the slot, then suitably decreasing the temperature of the melt until a button begins to grow from the seed.

If all goes well, the button grows with very little growth in width toward the ends. The button is then pulled up from the melt, and a web of single-crystal silicon grows between dendrites as the pulling continues.

According to the concepts that have prevailed up to now, the initiation of growth requires an undercooled melt. However, in this study, thermal calculations show that the melt remains above the freezing temperature. Instead, heat conduction through the solidifying material and heat radiation through the slot now seem more likely to effect the heat transfer necessary for solidification.

This concept was partly borne out in experiments on the growth of buttons, in which solidified material could be observed as highly radiating areas on the surface of the melt. The growth of a button is a self-propelling process: the emissivity of the solid (about 0.46) exceeds that of the liquid (about 0.22). Thus, with the solidification, the local radiative thermal loss increases, causing a decrease in local temperature and consequently further solidification of the melt.

The experiments also showed that buttons grow unpredictably in three distinct types. The factors that determine which type a particular button will be may include the symmetry or asymmetry of the temperature distribution, the orientation and placement of the seed crystal, and possibly the microscopic features of the contact between the seed crystal and the melt.

The large faceted surfaces observed on two types of buttons could not have coincided with the isotherm of the melting temperature. Temperature differences as large as 3 to 5 °C were estimated to have existed on the faceted solid/liquid interface during crystal growth. This observation indicates that a thermal analysis that excludes the crystallization kinetics can predict neither the shape nor the location of the solid/liquid interface.

This work was done by Robert Richter of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Study of the Mechanism of Single Crystal Silicon Growth in a Web Configuration," Circle 141 on the TSP Request Card.*
NPO-16964

Linear Anomaly in Welded 2219-T87 Aluminum Alloy

Microdensitometry can be used to distinguish between cracks and harmless anomalies in radiographs.

A study of the causes and significance of two types of linear anomalies (also referred to as weld-radiograph enigmas) that sometimes appear in radiographs of welds is described in a preliminary report. The anomalies are manifested as light or dark linear features parallel to the weld line in a radiograph of a weld. Dark anomalies can be mistaken for weld cracks. The study was undertaken because the anomalies were observed in welds in 2219-T87 aluminum alloy, the alloy used to make the Space Shuttle external tank.

A variety of causes of the anomalies were identified. These include the thermal distribution and the flow of liquid metal during welding; the development of microstructure, second-phase particles, and porosity during solidification; and the pattern of residual stresses after the weld has cooled. The absorption and diffraction of x rays by internal and external weld features also contribute to the anomalies.

The report contains diagrams and descriptions of phenomena that occur during the welding process. It includes microdensitometer traces from x-radiographs of actual welds and from computer simulations based on the calculation of x-ray transmission through assumed weld structures.

The report concludes that the anomalies are not unique to the 2219-T87 aluminum alloy and cites literature references for similar features in other alloys. Microdensitometer traces across suspect features show promise for distinguishing between linear anomalies and cracks: the anomaly images are less dense than crack images, the image-density difference for an anomaly being about 0.1 and that for a crack about 0.5.

This work was done by Wartan A. Jemian of Auburn University for **Marshall Space Flight Center**. *Further information may be found in NASA CR-178745 [N86-22685/NSP], "On the Determination of Linear Anomaly in the Macrostructure of VPPA Welded 2219-787 Aluminum Alloy — Preliminary Report."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. The report is also available on microfiche at no charge. To obtain a microfiche copy, Circle 55 on the TSP Request Card.
MFS-27152

Mathematics and Information Sciences

Space-Subdivision Algorithm for Abstract Trajectories

Computational overhead in testing links between nodes is reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

A computationally efficient algorithm facilitates the subdivision of *n*-dimensional spaces during the selection, testing, or optimization of trajectories in those spaces. The algorithm can reduce the cost of computation in such diverse problems as scheduling of interrelated events to avoid conflicts, devising efficient production-line layouts and operating schedules, routing telephone calls, and analyzing the motions of gas particles.

A problem of this type generally involves the search for the paths of many independently movable agents through the *n*-dimensional space. The agents are not allowed to collide, and their motions may be subject to optimality criteria (e.g., find the shortest possible path) or other rules (e.g., only forward motion allowed along the time axis or along one or more spatial axes).

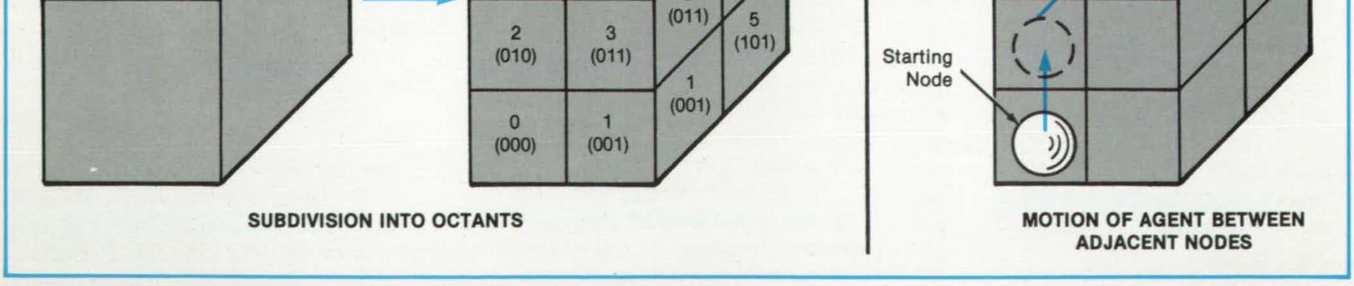
The algorithm is based on a binary encoding scheme related to the subdivision of the *n*-space, or of a previous subdivision of the *n*-space, into 2^n parts; for example, of a line into two halves, a plane into four quadrants, a cube into eight octants, or a four-dimensional hypercube into 16 hexidecants. The four-dimensional hypercube is particularly interesting because of its utility in the analysis of time-dependent trajectories of physical objects in ordinary three-dimensional space.

The figure helps to illustrate the three-dimensional application of the algorithm. Paths in three-dimensional space are analyzed in terms of octrees, which are the eight-branched trees corresponding to the octant subdivisions. When a subdivision is performed, each of the resulting octants is assigned a number in binary notation: the bitwise adjacency of those numbers corresponds to the spatial adjacency of the octants. If all travel between adjacent octants is through faces (not through edges or corners), then any motion from one octant to the adjacent octant can be represented by the change of a single bit. The directions and magnitudes of path segments between various nodes are thus easily calculated in binary submultiples of the largest octant-edge length.

Each octant is assigned a label that indicates its content (full, partial, or empty). The largest cube that contains all other octants is called the root node of the octree. To establish the preferred direction of travel of an agent, the path-planning algorithm is applied at a low order of subdivision representative of a coarse spatial resolution. The analysis then proceeds to the next higher level of resolution by making the next subdivision, descending into the octree from the intial node along the direction previously calculated. From this direction specification there must be generated an empty suboctree big enough to contain the agent, according to the rules of the specific problem.

Tree encoding for path planning provides a unified method for the solution of two-, three-, and four-dimensional problems, with time treated as one of the dimensions. The *n*-space subdivision enables the use of standard graph-searching techniques in the planning of paths. The algorithm quickly eliminates the portions of *n*-dimensional space that do not have to be tested; this reduces the computational overhead in testing links between nodes in a graph, so that more paths can be tried and better paths can be selected in less computation time.

This work was done by Douglas K. Lyon of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 21 on the TSP Request Card. NPO-16939*



A **Cube Is Subdivided Into Octants**, each of which represents a node along a path traveled by an agent. The movement of the agent from a starting node to a destination node is represented by a series of motions through the common faces of adjacent octants. Each unit motion is represented by a change of one bit in the binary enumeration of the octant.

FPT Algorithm for Two-Dimensional Cyclic Convolutions

The algorithm is regular, modular, and expandable.

NASA's Jet Propulsion Laboratory, Pasadena, California

A fast-polynomial-transform (FPT) algorithm computes the two-dimensional cyclic convolution of two-dimensional arrays of complex numbers. Whereas previous algorithms decomposed the problem into one-dimensional polynomial convolutions of different lengths, the new algorithm uses cyclic polynomial convolutions of the same length. Consequently, only fast polynomial and fast Fourier transforms of the same length are required. The algorithm is therefore regular, modular, and expandable. These qualities make it suitable for implementation in very-large-scale integrated circuits for template matching or other image-processing applications.

The problem is to compute the two-dimensional cyclic convolution of the two d_1-by-d_2 arrays $\{a_{t_1,t_2}\}$ and $\{b_{t_1,t_2}\}$, where $0 \leqslant t_1 \leqslant d_1 - 1$ and $0 \leqslant t_2 \leqslant d_2 - 1$. The convolution is defined by

$$C_{n_1,n_2} = \sum_{t_1=0}^{d_1-1} \sum_{t_2=0}^{d_2-1} a_{t_1,t_2} b_{(n_1-t_1),(n_2-t_2)}$$

where $(n_1 - t_1)$ and $(n_2 - t_2)$ denote the residues of $n_1 - t_1$ and $n_2 - t_2$ modulo d_1 and d_2, respectively.

With the help of polynomial transforms that sum over the indices t_2 and t_1, the two-dimensional cyclic convolution $C_{n_1n_2}$ is converted to a one-dimensional cyclic convolution $C_n(Z)$, where Z = the polynomial-transform variable. A new decomposition is chosen for a polynomial that appears in $C_n(Z)$. Additional transformations are introduced, and extensive manipulations are performed.

The net effect of the derivation is to provide for the calculation of $C_n(Z)$ through a seven-step algorithm that involves FPT's and has the desired modularity. The FPT technique is advantageous in that multiplications are replaced by cyclic word shifts. A generalized fast Fourier transform can be used to compute the polynomial products in one of the steps. The first step includes modulus reductions, and the last step includes reconstruction by the Chinese Remainder Theorem; both have butterfly flow structures similar to those of the fast Fourier transform.

This work was done by Trieu-Kie Truong, Howard M. Shao, D. Y. Pei, and Irving S. Reed of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 78 on the TSP Request Card. NPO-16835*

New Products

Measurements from 50 MHz to 26.5 GHz (over -70 to -20 dBm) can be made with one diode sensor and the new ML4803A Microwave Power Meter from **Anritsu America, Inc.**, Oakland, NJ. New "amorphous" thermocouple sensors permit measurements from 10 MHz to 32 GHz (-30 to +20 dBm), while providing low VSWR and high response speeds. **Circle Reader Service Number 574.**

An intelligent sensing system by **Namco**, in Mentor, OH can determine distance, angle, height and code readings. Data from Lasernet can operate automated guided vehicles without wire guide paths. In automated storage and retrieval systems, the system can ensure proper alignment between a crane's picking mechanism and material containers. Lasernet provides real-time information, updating every 50 milliseconds, and includes logic to provide 0-10 VDC analog outputs. **Circle Reader Action Number 579.**

Life Sciences

Hardware, Techniques, and Processes

Controlling Growth Rates of Protein Samples

The environment is made dry or wet to adjust the rate.

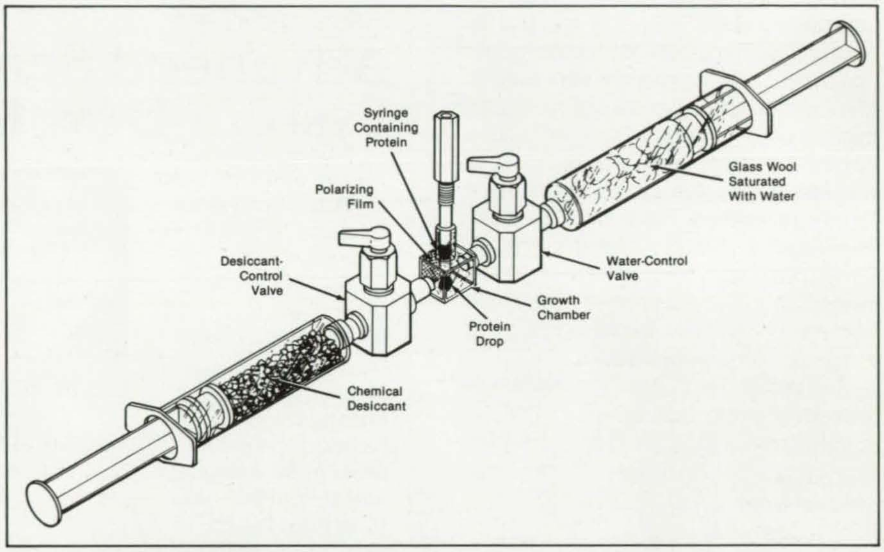
Mashall Space Flight Center, Alabama

An apparatus enables the control of humidity in a chamber to control the rates of growth of crystalline samples of protein. The size of the drop of solution from which the protein is grown can be made larger or smaller by the condensation or evaporation of water. Because the concentration of protein and precipitating agent are inversely proportional to the size of the drop, the change in size can be used to control the growth rate.

A syringe containing the protein solution is inserted into the growth chamber, and a drop of solution is forced from it so that the drop hangs from the syringe tip (see figure). An operator opens the valve between the chamber and a desiccant container. The drop shrinks as water evaporates from it into the desiccant. The operator observes the drop and, when it reaches the desired size, closes the desiccant valve.

If the drop becomes too small, the operator opens the valve to a water container. Moisture from the container condenses on the drop so that it expands. With valves, the operator can thus regulate the humidity in the growth chamber.

The apparatus can readily be adapted to automation. For example, a video image of the drop can be used to generate control signals for the valves. Several hundred samples could then be grown simultaneously without constant individual attention by an operator.



Situated Between a Desiccant and a Water Source, a drop of protein solution shrinks or swells, according to which valve the operator opens. The growing protein crystal is viewed through the polarizing film.

This work was done by Frederick T. Herrmann and Blair J. Herren of **Marshall Space Flight Center**. *For further information, Circle 138 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 14]. Refer to MFS-28182.

Mixing Valve for Protein-Crystal Growth

A multichamber unit combines reactants as necessary.

Marshall Space Flight Center, Alabamba

An apparatus for growing protein and other crystals holds reactants in separate chambers, then allows them to combine at the proper time. With a suitable design, a provision can also be made for a quenching agent to join the reactants when it is time to stop the reaction.

The apparatus was developed for protein-growth experiments in microgravity, in which crystal growth is unaffected by convection currents in the reactants. However, for some experiments it may also function in normal Earth gravity. It is compatible with the principal techniques for protein growth — the dialysis, batch, and liquid/liquid diffusion processes.

The apparatus consists of a series of opposed chambers separated by a rotary valve (see Figure 1). Passages inside the valve connect the chambers or isolate them, depending on the rotational position of the valve and its openings. O-rings and linear strips of elastomer on the valve prevent leakage between chambers.

Materials are introduced into the chambers through removable screwcaps at the outside ends of the chambers. Alternatively, material can be fed into a chamber by a syringe needle inserted through a polytetrafluoroethylene-coated silicone-rubber septum in the screwcap. A syringe can also be used to remove air from a chamber.

When the chambers have been filled, but before mixing, the valve passages are perpendicular to the chambers so that the chambers remain isolated. To initiate mixing, the valve is rotated 90°. This aligns the valve passages with the chambers so that

the contents of pairs of opposing chambers mingle and the crystal-growth reaction proceeds (see Figure 2). If a quenching agent is to be used to stop the reaction, the valve is rotated an additional 180° to release the agent to the chambers.

The apparatus can easily be automated. It can be enlarged to accommodate more experiments simply by adding modules of chambers. Multiple-step chemical syntheses can be carried out if enough passages are provided in the valve. The apparatus can be made from various chemically inert materials, and its chambers can be designed with capacities ranging from milliliters to liters.

This work was done by Daniel C. Carter and Mary Beth H. Broom of **Marshall Space Flight Center**. *For further information, Circle 158 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 14]. Refer to MFS-26047.

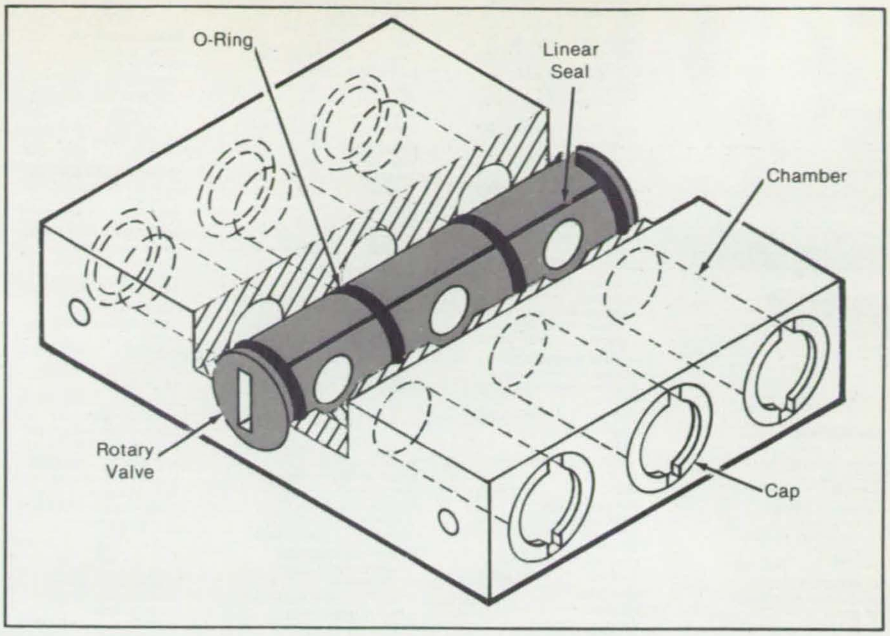


Figure 1. **Openings in a Cylindrical Rotary Valve** connect chambers to each other selectively through internal passages. O-ring and strip seals prevent leakage over the valve surface. Caps on the chambers seal them tightly but are removable for the addition of reactants or withdrawal of reaction products.

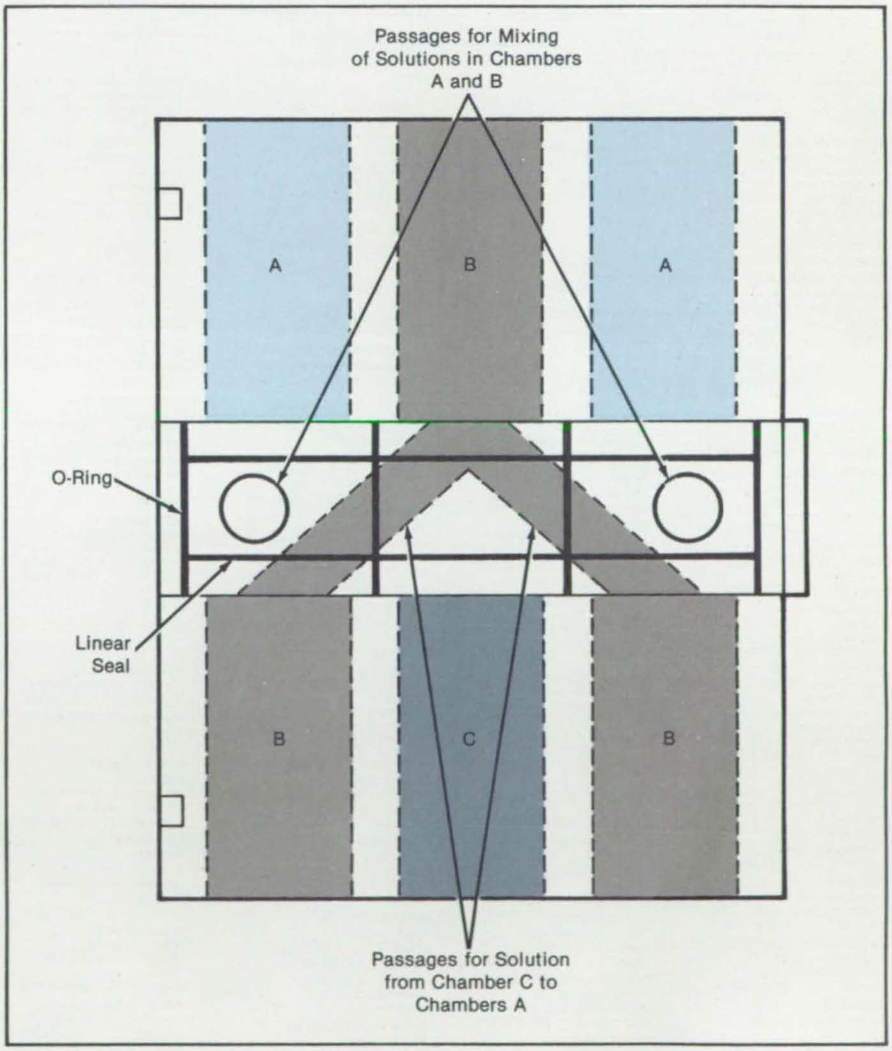


Figure 2. A **Cylindrical Rotary Valve**, shown here in cross section, is 90° from a position in which reactants A and B can mix and react. Rotation of the valve by 180° from the position shown would place it in a position in which the reactant C, a quencher, is released to chambers A.

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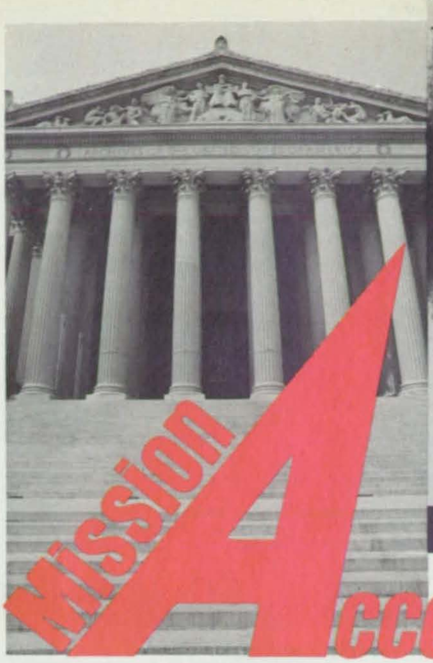


Mission Accomplished

While America festively celebrates the 200th birthday of its Constitution, conservators at Washington's National Archives are quietly working to save the document from the ravages of time. The key element in their effort is a NASA-developed imaging system designed to monitor the physical condition of not only the Constitution, but the Declaration of Independence and the Bill of Rights as well.

In the past, America's Charters of Freedom were subjected to a variety of harsh conditions. During the Revolutionary War, the Declaration of Independence was carried by wagon back and forth between eight cities. Later it was displayed in numerous government buildings where exposure to direct sunlight turned the parchment a deep yellow and faded the ink to the point of illegibility.

The National Archives, anxious to prevent further deterioration, turned to NASA's Jet Propulsion Laboratory (JPL) for help. Dr. Alan Calmes, National Archives Preservation Officer explained, "We were looking for technology that would provide us with an objective, repeatable method of assessing a document's condition. We simply had no real way of knowing when to take a document off of exhibit. . . until it was too late."

JPL scientists developed a monitoring system which incorporated imaging technology originally used to photograph planets from unmanned spacecraft. The Perkin-Elmer Corporation then designed and manufactured the system, which consists of a scanning camera and its accompanying image processing computer. This May, the "Charters of Freedom Monitoring System" was installed in the National Archives.

At the heart of the system is a charge-coupled device (CCD), a highly sensitive detector which serves as the electronic "film" for the camera. Similar CCDs are utilized on the Galileo Spacecraft and the Hubble Space Telescope's Wide-Field Planetary Camera.

The CCD can only "see" one narrow line at a time. Each line is divided into 1024 picture-element dots, or pixels. A linear motion system developed by the Anorad Corporation moves the camera over the document line by line until 1024 lines have been exposed. The resulting 1024-by-1024 pixel images are then stored in a computer data file. Each image records only a one-inch square portion of the document, divided into more than one million pixels.

Over time, conservators will be able to detect even microscopic signs of deterioration in the parchment pages by using the image processing computer to compare electronic images. Specific attention will be paid to changes in readability from ink flaking or fading, changes in document dimensions due to shrinkage, and enlargement of existing tears and holes.

The system can see "five times more detail than possible with the human eye," according to Dr. Calmes, who added, "We'll now be able to detect deterioration much more quickly than if we were relying solely on human judgement."

The National Archives is exploring other uses for the electronic camera, including methods of measuring the effects of conversion treatments on historical documents and authentication of works of art.

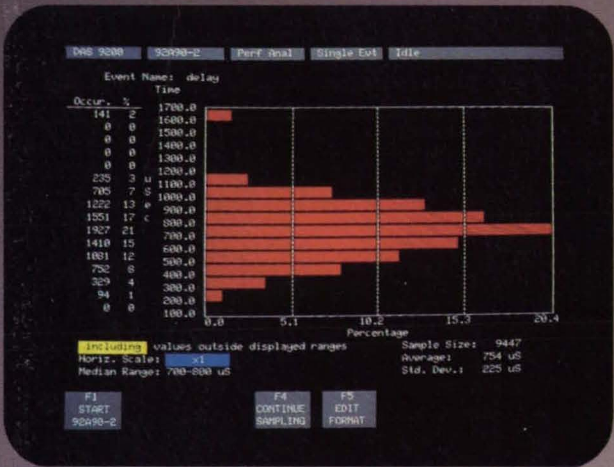
"We plan on using the system to analyze the nature of change," said Dr. Calmes. "Through accelerated aging tests we want to study how documents fare during lengthy exhibitions when exposed to fluctuating light levels, high temperatures, and other adverse conditions."

In July, Dr. Calmes held a meeting with representatives from major U.S. museums and galleries to describe the potential benefits of the technology. "The response was very positive," stated Dr. Calmes. "After further test and analysis, I believe interest in the system will grow tremendously and you'll see numerous applications."

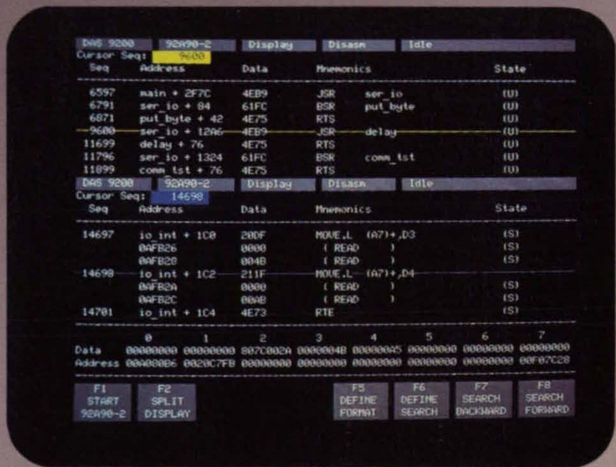
Meanwhile, Dr. Calmes is already looking forward to the Constitution's millennium celebration. "I expect the charter documents to live another thousand years and beyond," he said confidently. □

Utilizing a charge-coupled device, the electronic-imaging system takes precise pictures of the parchment through two layers of glass, producing a unique "fingerprint" record of the document.

DAS9200 DIGITAL ANALYSIS: NOW TEK MAKES THE IMPOSSIBLE LOOK EASY.



Software Performance Analysis, like this distribution of a subroutine's execution times, helps you easily understand the activity of your code.



Step backwards through acquired data, including subroutines, stack and register models, using time-correlated split-screen displays to pinpoint problems.

In every dimension— speed, channel width, memory depth, trigger capability, modularity and ease of use—the DAS9200 dwarfs what's been possible before.

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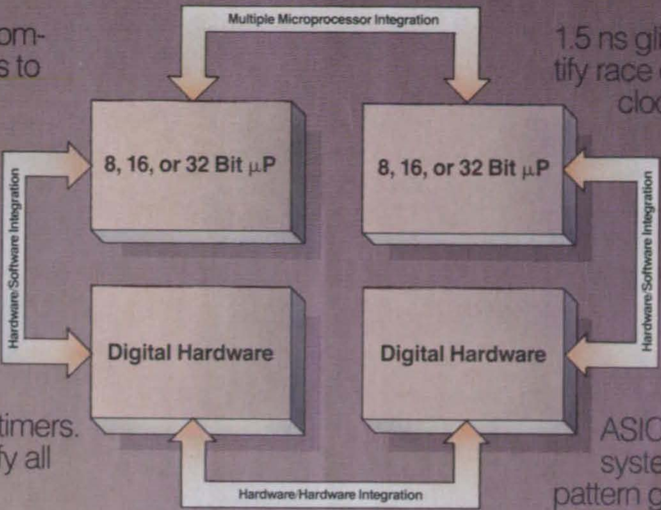

1 State-driven triggering at 200 MHz. You can use up to 384 channels of sync and async data acquisition. You can assurance-test high-speed logic at full speed, using 4-level state tracking and high-speed counter/timers. You can monitor and verify all timing measurements in a circuit.

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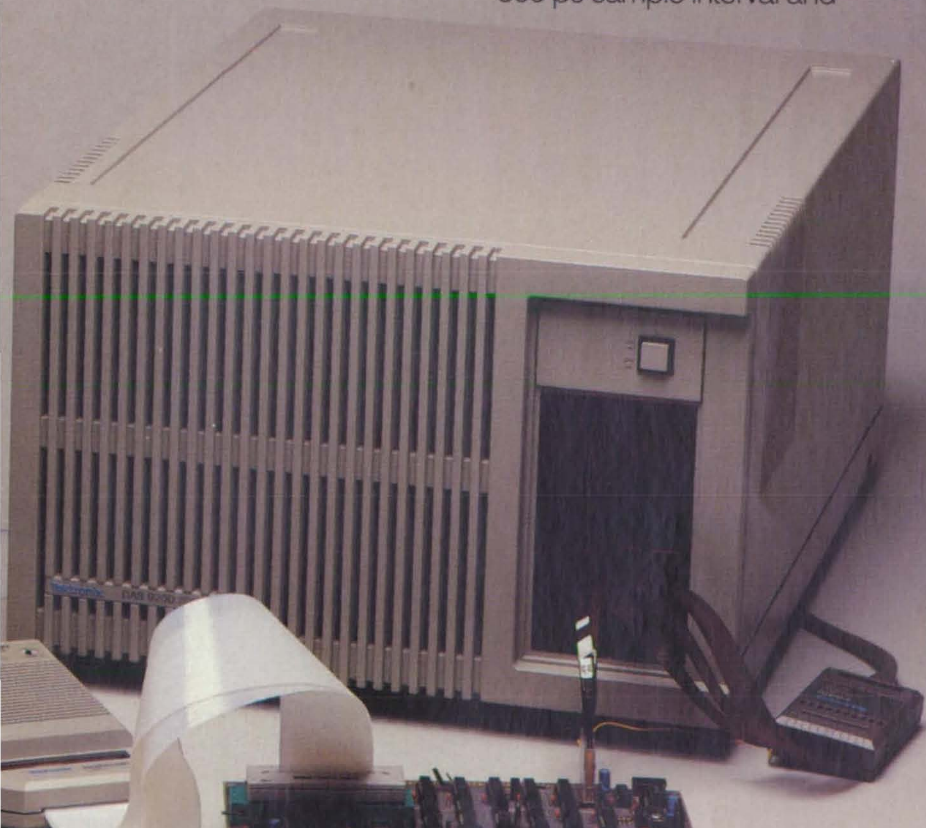

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